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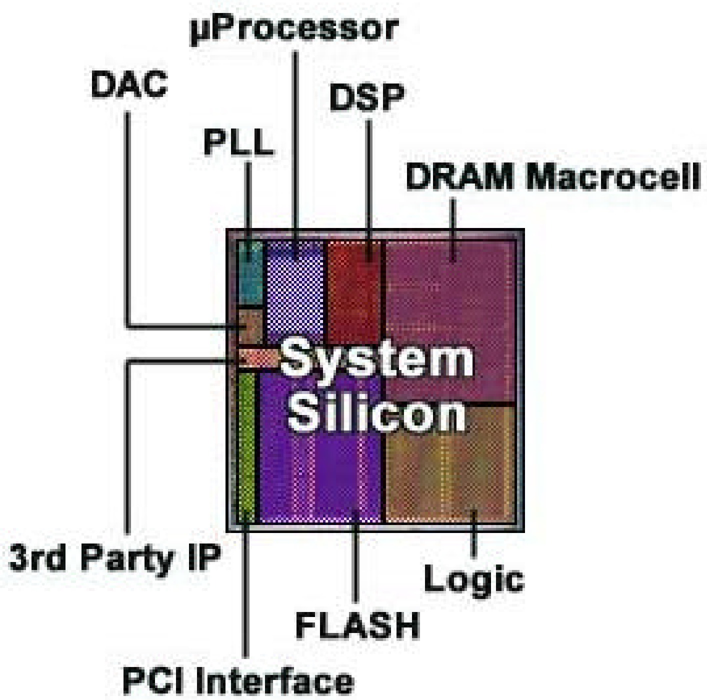
UTAH TECHNOLOGY REPORT

SYSTEM-ON-A-CHIP



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EXECUTIVE SUMMARY

The convergence of communications, computers and consumer electronics is driving the need for SoC. As technology companies migrate towards smaller, less expensive devices that are higher quality and have more functionality than traditional solutions, the growth of the SoC industry receives continuous fueling. As a result, in 1999, SOC shipments jumped 116% to 345 million units from 160 million in 1998. In addition, the SoC industry generated revenues of nearly $2 billion in 2000, a 153% increase over 1999 and In-Stat predicts that SoC volumes will grow an average of 31% a year, reaching 1.3 billion units in 2004. SoC already accounts for 20% of the billion-dollar semiconductor market, and it is projected that this figure will grow to 60% within the next five years.

In order to aid Governor Leavitt and the Utah Silicon Valley Alliance in accelerating Utah's emergence as a center for technology and entrepreneurship, this document was written to achieve the following three objectives:

- Characterize the SoC industry

- Make recommendations based on industry observations that will help Utah become an SoC technology hub

- Create a list of key industry players that could play a strategic role in the formation of an SoC hub in Utah

In conducting our research, we relied on four major areas of research:

- We interviewed 6 executive officers from companies that are major players in the SoC industry. In addition we conducted interviews with market analysts and researchers who specialize in semiconductor industries.

- We created an electronic survey using the services provided by www.surveypro.com that was completed by 20+ companies that are players in the SoC arena. This survey asked for information such as basic company financials and the perception of Utah's technology business environment. In response to Utah's technology business environment, 65 % of respondents gave an "average" ranking, 20 % gave a "weak" ranking, and 15 % gave a "strong" ranking.

- We used the Compustat business database to download financial information about technology companies across the US. This information was then used to compile industry financial descriptives on both the national and regional levels. It was our intent to compare the SoC specific financials within the State of Utah to the national average. Due to the lack of SoC companies within the State (and the even greater lack of data available on Utah players) this was not possible. However, we were able to conclude, based on a long string of negative yearly Return on Equity (ROE), that the SoC industry is experiencing growing pains. One cause for a negative ROE is when a company spends more than it makes. In other words, SoC companies are investing everything they have and them some into growing their companies.

- We relied extensively on secondary research. This research was almost exclusively conducted on the Internet. Information such as company descriptives, financials (for public firms), and contact information was collected using this method.

We feel as though we were successful in achieving the objectives for this study as outlined above. In doing so we have concluded that the SoC industry is one that has enormous growth potential and is therefore a high priority to the State of Utah.

FINDINGS

Observation #1: Since most technologies can be imitated, backward engineered, or merely copied, the barriers to entry such as intellectual property protection are key to sustainable prosperity in the SoC industry.

Observation #2: States that emphasize R&D and have a comparative advantage in innovation do not always reap large economic rents because profits flow primarily from efficient, large-scale manufacturing.

Observation #3: Since companies have countervailing product development incentives, they must minimize time-to-market but are also compelled to maximize quality assurance and design robustness through more lengthy development periods. Winning firms will manage the time-quality tradeoff better than their competitors.

Observation #4: Design reuse denotes the process of leveraging work that goes into creating a chip today, for multiple uses in different applications tomorrow. Firms that can implement the "design-for-reuse" business model will gain a strategic advantage over firms that learn more slowly.

Observation #5: SoC innovations are now the focus of all major players in the semiconductor space, and reflect a continuum of industry evolution towards smaller, lower maintenance, and lower cost devices and applications.

Observation #6: Despite the supposed existence of "first mover" advantages, first-to-market innovators with new products and processes do not always win. Situations where firms were first to commercialize a new product, but did not participate in the profits that were subsequently generated from the innovation, are increasingly common.

Observation #7: There are many chemicals and other toxic agents that are used in the production of semiconductors. Naturally, these are the same wastes that would be associated with the SoC production process. The processes that create waste are crystal processing, wafer fabrication, final layering and cleaning, and assembly. All portions of these processes must comply with both the Clean Air Act (CAA) and Clean Water Act (CWA).

Observation #8: The SoC value chain has six links. They are:

1. EDA Tools
2. IP Providers
3. Design Services
4. Chip manufacturing
5. Applications software
6. Systems Companies

IP Providers and Design Services are the two links that provide the greatest potential for ROI and profits.

Observation # 9: There are over 250 established companies that are chip vendors, 100 or more companies involved in fabrication equipment and materials, and numerous companies that reside in the software and services sector. Furthermore, there are countless, most likely thousands, startups in the SoC space.

Observation #10: The SoC industry is difficult to segment. Because of the convergence within the semiconductor industry, traditional lines that separate firms are blurred. Methods such as industries served or services offered don't directly apply. Because of this, segmentation was done using both methods. First, companies were screened by industries served. SoC companies in the communications, computer, and consumer segments were selected as areas in which to identify target companies, since together these segments comprise over 80% of the SoC industry. Second, companies were again screened by services provided. The design & intellectual property services were chosen from the companies that serve the communications, computer, and consumer segments.

Observation #11: Key indicators of leadership in the SoC industry are customer relationships, quality of service, keen insight, strategic execution, product features, and partnerships formed. Based on company size, along with criteria listed above, the following is a brief list of companies identified as leaders in their respective industries:

Communications:	Broadcom, inSilicon, Motorola
Computer & ECP:	IBM Microelectronics, LSI Logic, Toshiba
Consumer:	Cadence Design Systems, Matsushita
Design & IP:	Cascade Design Systems, Avant!, Palmchip
Manufacturing & Production:	Taiwan Semiconductor, Micron
Testing and Verification:	Mentor Graphics, Synopsys, Teradyne

Observation #12: Communications products are the largest market segment for SoC design. Telecommunications is a prominent and steadily growing industry that SoC providers can capitalize on. Approximately $200 billion is spent in the U.S. each year on communications; $50 billion is for long-distance calls. SoC technology can play a key role in this process, enabling telecom companies to integrate leading-edge chip technology that expands the functionality and utility of their devices, ultimately maintaining a competitive edge within their sector and encroaching into competing sectors with multi-functional devices.

Observation #13: Data communications is an exploding market, growing at Internet speed. By the end of 1999, over 200 million people were online worldwide. In the chip sector, the smart home networking IC market will experience aggressive growth, growing from a mere $41 million in 2000 to over $650 million in 2005.

Observation #14: Over the next several years the consumer products segment will grow the fastest in the market, averaging an increase of 43% per year through 2004. A large part of this growth is due to a proliferation of "converged" services including Internet appliances, PDAs, multifunction cell phones digital cameras, spurred on by an industry wide migration towards the convergence of communications, computers, and consumer electronics. Over the next several years the Internet appliance market will heat up, with sales growing over 40% per year between 2000 and 2005. Cahners In-Stat group estimates the sales of the Internet Appliance microprocessors alone will jump from $18 million in 2000 to $91 million in 2005. Related technologies such as flash and DRAM sales will also experience growth, at 5% and 26% respectively. The demand for SoC designs will grow due to the growth in this segment.

Observation #15: Overall audio sales for 2000 reached $7.2 billion, increasing 9%. In this area, the portable audio sector shows that most portable compressed audio, MP3-type players, sales totaling $107 Billion for approximately 587,000 units. SoC design and IP are used in such making of such devices.

Observation #16: 78% of the survey respondents labeled a locally available, highly skilled technical labor force as “very important.” Local research institutions, quality of life, and cost of living also emerged as important criteria in the decision to relocate or expand. Utah currently has many of the elements most important to companies in the SoC industry, including a skilled workforce, local universities, a high quality of life, and a reasonable cost of living.

Observation #17: Despite what Utah has to offer the perception of Utah is still average. When asked to rate Utah's overall technology business environment, 65% of respondents gave an “average” ranking, 20% gave a “weak” ranking, and 15% gave a “strong” ranking. No respondents chose “very weak” or “very strong.”

Observation #18: Nothing of real effect is being done to achieve the Governors goal of doubling the number of engineering college graduates in 5 years and tripling the number in 8 years. Many of the College of Engineering professors in the State feel as though the are being told to perform a miraculous feat without being given the resources.

RECOMMENDATIONS

Recommendation #1: Recognize that science and technology alone will not provide sufficient foundation to guarantee economic growth. Targeting the innovation process requires attention to the capacities complementary to innovation. In particular, manufacturing matters. So does infrastructure. Strategic alliances confer benefits when it comes to developing and capturing value from innovation. While strength in capacities complimentary to R&D will promote economic welfare where imitation is easy, it is not the only solution. A company with outstanding technology and an excellent product can fail to profit from innovation while the imitators succeeded. Focus R&D programs on delivering innovations that will have a good chance of benefiting you rather than your competitors. In addition, the State must do all it can to bring the entire SoC value chain to Utah and encourage its members to form strategic alliances. The key to success for any link in the SoC value chain will be in establishing partnerships in order to provide complete solutions to compelling customer problems.

Recommendation #2: The perception of Utah’s high tech business environment will need to be improved before companies will show an interest in locating within the state. If 65% of the high tech world sees Utah as an average place to do business, with an additional 20% that see Utah as week, the chances of a CEO even considering Utah as a place to expand or relocate are highly unlikely. Utah must find a way to get into the minds of business men all over the world, so that when it comes time to move or relocate Utah will be at the top of the list of places under consideration. Utah must strive to own key words in the minds of businessmen.

Recommendation #3: Focus on large firm expansion and medium-sized private firm relocation. This assumes the current situation of nonexistent second- and third-round venture capital will not change in the short term. Utah hosts a few large firms and many startups but homegrown companies frequently exit before reaching IPO and maturity (VC report). Until the VC financing problem is solved Utah will not be able to home grow their own companies. Firms will have to continue to look outside the State for VC funding. Firms like the San Jose-based CPUTech have committed to relocate in Utah only after their capital needs were met by outside investors.

Recommendation #4: Utah must take a two-pronged strategy to building high tech industry in the State. Utah should simultaneously induce anchor companies to expand here and draw mature private firms to relocate here. This two-pronged strategy is derived from the debate surrounding how to effectively nurture and grow an industry -- cluster economies versus anchor companies. On the one hand, economies of agglomeration within industries emerge only after a "critical mass" of companies resides in close proximity to one another. On the other hand, the presence of several anchor companies or large industry leaders generates incentives for supplier and customer firms to follow. Utah can hedge itself by following this two-pronged approach. The continued state economic expansion largely hinges on the success of advanced technology economies in the state; by all accounts increasing the state's semiconductor industry should boost the Utah's position an emerging national technology hub. Growing the SoC industry will advance this end.

Recommendation #5: Utah must take advantage of opportunities that already exist in the State. Utah hosts a growing number of satellite offices for major semiconductor firms including Intel, Lucent, Fairchild, and National. While these offices are typically small sales entities, the opportunity exists for greater government outreach. State officials would do well to engage local company principals with the same enthusiasm that is shown to firms exploring relocation and expansion. This fits perfectly with recommendation #1 that advises the encouragement of partnerships between companies. Since the fruits of scientific effort are increasingly open to all with the capacity to receive, extracting value from a nation's science and engineering prowess will require its firms to have competitive capacities in certain of the key complementary assets, such as manufacturing and marketing. These satellite offices can be a source of partnerships for future Utah located SoC firms.

Recommendation #6: Utah must focus on the present if it wants to have the resources for the future. In order to have trained people ready for employment by future Utah companies, the number of new college enrollees must be increased now. Governor Leavitt has stated that he would like to see the number of Engineering College Graduates double in the next five years and triple in the next eight. If there is to be a doubling of graduates in five years in a four-year program, the number of students enrolling in these programs must be doubled now. We do not view this as a problem that is possible to fix in the short term. If students are going to be guided into engineering programs, they must be encouraged from a young age. In other words, encouragement needs to start in grade schools and middle schools. In addition, a doubling in the number of engineering college graduates will require a doubling in resources. If this doubling is truly the goal, Utah must increase funding to the state universities so that they can expand their programs.

TARGET COMPANY LIST

Below is a list companies, and contact information for each, that should be targeted with the goal of either relocating to or expanding into Utah. Among these 15 companies identified as target companies, 10 are large, public firms that would act as anchor companies. The remaining five recommended companies are established, pre-IPO firms that have tremendous potential for growth and success. Because Utah's current environment does not support smaller start-ups well (due to the lack of venture capital), the targeted private companies are more mature and generally are close to or have completed their third round of financing. This will help ensure that they have the ability to continue to thrive in Utah's environment.

Company	CEO	General Phone #
Communications:		
Agere (Allentown, PA) www.agere.com	John T. Dickson	(610) 712-4323
Broadcom (Irvine, CA) www.broadcom.com	Henry Nicholas	(949) 450-8700
RealChip (Sunnyvale, CA) www.realchip.com	John Zucker	(408) 735-9065
Triscend (Mountain View, CA) www.triscend.com	Stanley Yang	(650) 968-8668
Zeevo (Santa Clara, CA) www.zeevo.com	Anil Aggarwal	(408) 982-8000
Consumer Electronics:		
ARM (Los Gatos, CA) www.arm.com	Robin Saxby	(408) 579-2200
Cadence (San Jose, CA) www.cadence.com	Ray Bingham	(408) 943-1234
inSilicon (San Jose, CA) www.insilicon.com	Wayne C. Cantwell	(408) 894-1900
MIPS (Mountain View, CA) www.mips.com	John Bourgoin	(650) 567 5000
Computers & EDP:		
LSI Logic (Milpitas, CA) www.lsilogic.com	Wilfred Corrigan	(866) 574-5741
STMicroelectronics (Carrollton, TX) www.st.com	Pasquale Pistorio	(972) 466-6000
Design & IP:		
Avant! (Fremont, CA) www.avanticorp.com	Gerald. C. Hsu	(510) 413-8000
CPU Tech (Pleasanton, CA) www.cputech.com	Edward King	(925) 224-9920
Mentor Graphics (Wilsonville, OR) www.mentorgraphics.com	Walden C. Rhines	(503) 685-7000
Palmchip (San Jose, CA) www.palmchip.com	Jauher Zaidi	(408) 952-2000
Tensilica (Santa Clara, CA) www.tensilica.com	Chris Rowen	(408) 986-8000

High Technology in Utah is a hot topic. The State wants to grow its technology sector. There is no better way to achieve this than by attracting high growth segments of the technology industry. The SoC segment of the high tech industry has huge growth potential. If Utah is successful in establishing itself as an SoC hub, it will be well on its way to creating its own Silicon Valley.

PREFACE

Escalating in the mid-1970s, state economies all around the country augmented dramatic shifts from mining, agriculture, and smokestack industries toward advanced technology. Several intermountain states including Utah took steps to attract computer and software firms in an effort to diversify and develop high tech industries. Silicon Valley increasingly stands as the paragon of the technologically based industry, but has experienced diseconomies of agglomeration due to crowding and traffic effects as well as serious energy shortages. Notwithstanding its relatively small scale, Utah possesses many essential components for high tech prosperity including strong research universities, several large, nationally visible anchor companies, and a well-educated workforce.[1]

High technology firms in Silicon Valley and other regions, therefore, have growing incentives to "build out" of California; Utah appears well positioned to capture firm expansion and relocation. Accordingly, Governor Leavitt has initiated the Utah / Silicon Valley Alliance as the research and marketing arm of the State's economic development efforts.[1] The Governor's technology task force subsequently identified several industries for intensive study, not the least of which is the emerging system-on-a-chip (SoC) business. The following report attempts to characterize the industry through the presentation of statistics, description of market trends, and analysis of the Utah's ability to host a growing number of locally grown SoC firms, as well as induce out of state companies to do business in the state. Ultimately, this report makes observations about the industry at large and identifies specific firms that could potentially thrive in Utah's burgeoning high technology milieu.

The question of continued national economic expansion largely hinges on the success of advanced technology economies in *and* outside of California, thus suggesting the importance of state development efforts. This report presumes that California excels in all stages of firm development—startup, expansion, IPO, and maturity; most other regional economies including Utah, however, lack the wherewithal to efficiently nurture firms in all four stages. Utah hosts a few large firms—and many startups—but these companies frequently exit before reaching IPO and maturity. A recent DCED-commissioned report on venture capital affirms the absence of sufficiently large funds for second and third round financing essential to rapid growth beyond startup.[2] Assuming the funding problem is fixed in the short term, this report advocates a development strategy focusing on large firm expansion and medium-sized private firm relocation.

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[1] The Alliance falls under the governance of the Department of Community and Economic Development, Division of Business and Economic Development, Office of Technology Development.

WHAT IS SYSTEM-ON-A-CHIP?

Industry insiders increasingly tout advances in system-on-a-chip (SoC) technology as "revolutionary." Consistent with such rhetoric, major corporate players are devoting generous resources to SoC research and development. Today SoC-related products account for about 20% of the semiconductor market, and some predictions suggest that SoC output will approach 60% within the next five years. SoC, also known as System Silicon, System Level Integration (SLI), Multi-Chip Modules (MCM), Stacked Die, Multi-Die Package, connotes the growing integration of analog, digital, and memory circuits on a single piece of silicon. Analysts anticipate that the SoC market will crest $16 billion within three years.[3]

More than a decade ago, memory constituted the primary driver of semiconductor industry growth. However, when Japanese companies entered the picture and amassed a substantial share of the memory market in the mid-1980s, their success forced competitors out of memory and into other markets. Intel, for example, abandoned dynamic random access memory (DRAM) and shifted the focus of their business squarely on the microprocessor, and more recently towards SoC design and applications.[4]

Today SoC-related products account for about 20% of the semiconductor market, and some predictions suggest that SoC output will approach 60% within the next five years.

Today, the semiconductor industry is segmented into four general categories: memory, microprocessor, commodity integrated circuit (IC) and complex SoC. The consolidation of the memory market has continued, driving memory prices so low that only a few giants (e.g., Samsung, NEC and Toshiba) can afford to stay in the game. Similarly, Intel's legendary success in the microprocessor segment has forced everyone but AMD out of the mainstream and into smaller niches or different market segments entirely. The third category, commodity devices, offers such razor-thin profit margins that the vast majority of semiconductor companies just aren't interested, opting instead to bet the farm on the fourth and final category: complex SoC. With the doors to the other three categories tightly shut, this category is the only one left with enough opportunity to attract a wide range of companies. For many household names, this type of IC may be a key source of survival.[5]

More specifically, system-on-a-chip is a complex semiconductor chip aimed at a system-level solution. All of the elements of a system are combined on a single chip, which may include high-performance CPU cores, large blocks of memory, one or more mixed-signal or analog blocks, FPGA blocks, functional blocks, and embedded APIs or other software.[6] Generally, system-on-a-chip designs have been defined as ICs with embedded processors, memory, and other functions that make them much more complex than basic building-block semiconductors.[7] SoC also connotes the ability to take all the electronic circuits that previously required one or more printed circuit boards and place them on one chip.[8] An SoC's construction includes one or more processing elements, application-specific silicon IP, storage elements and, frequently, analog functions. What sets an SoC apart from an ASIC or ASSP is that an SoC's embedded-processing element(s) and application-specific IP have more bandwidth, are more application- and customer-specific, and can achieve higher levels of integration.[9]

What sets an SoC apart is that an SoC's embedded-processing element(s) and application-specific IP have more bandwidth, are more application- and customer-specific, and can achieve higher levels of integration.

What is driving the push for SoCs is the advantages they bring to those determined enough to design them: lower cost, greater reliability and lower power.[10]

BROADER INDUSTRY CONTEXT

Semiconductor industry revenues in 2000 were about $200 billion, up 35% from 1999. Growth in the telecommunication services industry has spurred a corresponding boom in the semiconductor business. The personal computer industry is the most significant sector for semiconductor manufacturers. The explosive growth of the Internet and the need for added bandwidth will create more demand for high performance semiconductor chips.[11]

The explosive growth of the Internet and the need for added bandwidth will create more demand for high performance semiconductor chips.

However, because of a recent downturn in the cyclical semiconductor industry, many companies expect weak revenues in 2001. Specifically, commodity chips could experience intensive financial pressure. Currently, the environment is completely reversed as worldwide semiconductor revenue is projected to be $188 billion in 2001, a 17 percent decline from 2000, according to the latest forecast by Dataquest Inc., a unit of Gartner, Inc.

"In 2001, all product types are seeing a serious decline in revenue, with the DRAM- and Flash-heavy memory category dropping 26 percent. In 2002, memory is expected to grow at roughly 26 percent, but this will not return the revenue to its $68 billion high of last year," said Tom Starnes, chief analyst for Gartner Dataquest's worldwide semiconductor group. "Semiconductor markets are expected to expand from 2002 to 2004, but near the end of 2004 or into 2005, the traditional imbalance of too much product is expected to appear again, initiating the next phase of the semiconductor cycle. "

A fairly slow recovery is expected to bring 2003 revenues to $213 billion, growing 13 percent (see table below). The semiconductor industry won't see revenue totals match the results in 2000 until sometime in 2004 when the industry is projected to reach nearly $265 billion.

Worldwide Semiconductor Forecast (Millions of U.S. Dollars)

	2001	2002	2003	2004	2005	2006
TOTAL MARKET	226,228	188,400	213,300	264,900	346,500	336,900
Growth (%)	32.5	-16.7	13.2	24.2	30.8	-2.8

Source: Gartner Dataquest (May 2001)[12]

SoC Growth Outlook

The ASIC- and SoC-rich logic category should see the highest overall compound annual growth rate in the semiconductor market through 2005, topping 10 percent.

The ASIC- and SoC-rich logic category should see the highest overall compound annual growth rate in the semiconductor market through 2005, topping 10 percent.[13] Cahners In-Stat Group predicts that the system-on-a-chip business will exceed 1 billion units in 2004, compared to about 345 million devices last year. In-Stat predicts that SoC volumes will grow an average of 31% a year, reaching 1.3 billion units in 2004. About 39% of the SoC devices served communications systems applications last year, according to In-Stat.

"Time-to-market pressures and the need for more functions in system products are fueling the SoC growth."

--Max Baron, Cahners In-Stat

Time-to-market pressures and the need for more functions in system products are fueling the SoC growth, said Cahners In-Stat analyst Max Baron. "They must have efficient access to designs that have been previously tested," he said, referring to the need for intellectual property (IP) design blocks used to build system-on-chips. [14]

Factors that will impact the market beyond the year 2000 include a range of new manufacturing and production techniques that will drive the SoC market in the near future. These factors include:

- The move to 300mm wafers.
- The introduction of copper interconnects into mass production.
- The introduction of SiGe processes into mass production.
- New high-k dielectric materials to help reduce transistor gate oxide thickness.
- Potential use of new transistor architectures.
- Move to tighter design rules for ASIC designs: 0.25 micron now to 0.10 micron by 2005.
- Emergence of "Cost-effective"-SoC (C-SoC) and "Performance"-SoC (P-SoC).

SoC's share of the global chip business will soar from 3.4% in 1998 to 17.2% by 2003.

All these changes are poised to occur over the next four to six years. Overall, the market numbers for SoC look extremely bullish. It is projected that more than 25% of total units shipped in 2000 will be in the SoC category. This percentage is estimated to grow to almost 70% by 2003.[15] SoC's share of the global chip business will soar from 3.4% in 1998 to 17.2% by 2003, according to estimates from Electronic Trend Publications, San Jose. The value of ICs with enough integration to be classified as SoC devices will jump nearly tenfold, from about $3.7 billion last year to $34 billion in 2003, the report said.[16]

SoC in Historical Context

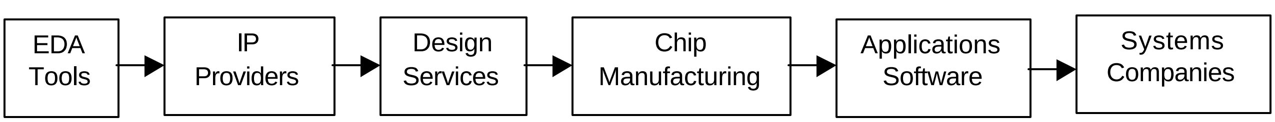
In 1965, seven years after the integrated circuit was invented, Gordon Moore observed that the number of transistors that semiconductor makers could put on a chip doubled every year. Moore, who co-founded Intel Corporation in 1968 and is now an industry sage, correctly predicted that this pace would continue into at least the near future. The phenomenon, known as Moore's Law, has had far-reaching implications. Because the doublings in density were not accompanied by an increase in cost, the expense per transistor was halved with each doubling. With twice as many transistors, a memory chip can store twice as much data. Higher levels of integration mean greater numbers of functional units can be integrated onto the chip, and more closely spaced devices, such as transistors, can interact with less delay. Thus, the advances gave users increased computing power for the same money, spurring both sales of chips and demand for yet more power.[17]

Chips are becoming so large and complex -- and market windows are becoming so short -- that companies can't hire enough engineers or buy enough technology to avoid hitting a limit on how much design complexity they can handle

To the amazement of many experts (including Moore himself) integration continued to increase at an astounding rate. True, in the late 1970s, the pace slowed to a doubling of transistors every 18 months, but it has held to this rate ever since, leading to commercial integrated circuits today with more than six million transistors. Successive roadblocks, however, have become increasingly imposing, for reasons tied to the underlying technologies of semiconductor manufacturing.[18] Chips are becoming so large and complex -- and market windows are becoming so short -- that companies can't hire enough engineers or buy enough technology to avoid hitting a limit on how much design complexity they can handle. As the industry moves to smaller process technologies, it has become possible to produce single chips with tens of millions of transistors, therefore enabling system-on-a-chip designs. At the same time, because most SoCs target fast-moving consumer applications, design time is shorter than ever.

VALUE CHAIN DESCRIPTION

To understand what components of an industry to target, one must first have an understanding of the value chain. Once familiar with all the links in the chain and how each one specifically adds value to the end product, it is then possible to make a decision as to which links are the most important and the greatest likelihood at sustaining profits. The flow chart shown below shows each link in the SoC value chain. Following the flow chart is a description of each link in the chain that tells how each link contributes value to the final product.



Source: Chart adapted from "Crossing the Chasm with System on a Chip "[19]

EDA Tools → Electronic Design Automation Tools provide an integrated front-end design environment for system-on-a-chip, that includes ESL, RTL and gate-level design. John Daane, executive vice president of LSI Logic states that there is a growing concern for the future of the SoC industry because "the complexity of the technology for an SoC far outpaces what we're seeing in the EDA industry." While this kind of demand is good for the EDA tool providers, IP providers might be stagnated by their available design tools. In other words, in order to keep up with the pace of technology, the providers of EDA tools specific to the SoC industry are going to have to produce higher quality tools in a shorter period of time. This is key to SoC being able to disrupt the market. If the EDA tools SoC designers have to work with slow the design process, SoC will miss out an opportunity to overtake the semiconductor market.

IP Providers → Reusable intellectual property is critical in the SoC industry. Because every system designed is unique in nature, the design process can be time consuming. One way of working around this time constraint is to incorporate reusable IP blocks into a design wherever the design will allow it. Analyst Max Baron said in *Semiconductor Business News* that when existing IP blocks are used in conjunction with proprietary IP, these IP blocks can be the foundation of any given SoC design while still allowing the chip to be custom tailored to the specific design requirements allowing a faster time to market.

There is a growing concern for the future of the SoC industry because "the complexity of the technology for an SoC far outpaces what we're seeing in the EDA industry."

-- John Daane, Executive VP, LSI

If IP providers can produce more easily reusable blocks of IP, the rate of innovation in SoC design will substantially increase -- bettering its chances to disrupt the market (se Appendix 2).

If a design goes to mask and doesn't function properly, the required respin can add several months to the design process and cost as much as $250,000.

Design Services → The role of the design service is to first define the chip at the behavioral level and then separate it into its software and hardware components. Currently, 20 percent of all man-hours are spent on hardware design and 80 percent are spent on software design. It is the designers that bring in IP from all sources--an in-house source, a silicon provider, or a third party. Through the design process, designers focus on software or circuit development, which includes functional design and verification, gate and circuit-level implementation, and physical layout. Verification costs at least as much in time and money as any portion of the design process. If a design goes to mask and doesn't function properly, the required respin can add several months to the design process and cost as much as $250,000. At the end of the design phase the hardware and software are taken into prototype.

Chip Manufacturing → This is the most well-known and capital-intensive link in the value chain. The cost of opening shop is a barrier to entry into this portion of the chain. In 1999, the cost of constructing a manufacturing facility was $3-4 billion.[20] In addition, the cost of quality assurance is rising. The integration of memory, mixed signal, IP cores, and embedded microprocessors into a single SoC is simultaneously a technical marvel and a test nightmare. IC test equipment costs are going sky high, inflated by higher densities, higher capital costs, multi-pass testing, longer test time, and combined function testers. The result: per-unit test costs are rising more rapidly than any other aspect of IC manufacturing.

Chip manufacturing is the most capital intensive of all the links in the value chain.

Applications Software → At this link in the value chain, software applications are written that allow the SoC to be used for a specific application. This link falls into the category of general software development. An example of this is the Palm operating system (OS). Palm Pilot, Handspring Visor and other PDAs all function beautifully, but only because of the Palm OS. The operating system is what gives those PDAs, or SoCs, a specific application.

Systems Companies → These are companies that sell the SoC in conjunction with the application software in the form of a complete system ready for use by consumers. Again, drawing on the Palm example, these are companies like Palm, Handspring, Casio, and Sony that are selling a final, application specific product.

INTERESTING VALUE CHAIN FINDINGS

A number of interesting trends in the SoC value chain should be discussed at this time. The first falls into the IP Providers link, the second into the Design Services link.

IP PROVIDERS

Three schools of thought exist surrounding the issue of reusable IP. The first school claims that reusable IP is the only way to achieve the economies of scale and time to market necessary to make SoC viable. Roger Strukhoff and John A. Barry in their article "IP or not IP? That is the Question" said, "Virtual components allow design reuse. Design reuse closes the productivity gap and enables the design of complex system-chips."[21] The second school claims that every design is unique and therefore no old IP would be applicable to current design projects.

The third school of thought tends to support the first school's claim that reusable IP is applicable to SoC design but adds one condition: that although the reusable IP approach is applicable, current IP blocks are difficult to work with. A lot of

IP from disparate sources often comes in disparate forms, written in different styles and languages. It then becomes difficult to integrate, synthesize, and verify several pieces of IP in one SoC.

available IP has been generated for decades, but the problem is actually reusing the IP in a design team without the original developer. "SoC designers should give up hope of reusing much of the existing IP," said Robert Ristelhueber of *EE Times* in his article entitled "Intellectual-property issues stall SoC designs."[22] IP from disparate sources often comes in disparate forms, written in different styles and languages. Because no standard governs IP development, it becomes difficult to integrate, synthesize, and verify several pieces of IP in one SoC. Even newer IP blocks that were designed with the intent to be more flexible are also difficult to use.

To date, design-for-reuse methodologies have focused on the creation of soft, flexible, reconfigurable IP blocks that are then modified to meet the specific requirements of the application. In an article entitled "The Transition to System-on-a-Chip", Lee Todd and Andy McNelly claim that this synthesis-centric approach has yielded inadequate productivity improvements. Further, they stated that with further enhancements to documentation, support, and access mechanisms, productivity could be expected to grow to 1.5-3X over conventional block-based design. However, SoCs will require a more than 10X productivity improvement to meet time to market windows.[23]

Despite these facts, Brian Lewis reported "Semiconductor intellectual property is the cornerstone of the SLI/SoC market."[24] Only a small number of IP suppliers have been able to establish themselves as mainstream IP providers to the masses and capture substantial profits to reinvest in the development of next-generation IP. "Hot" IP cores include microprocessor cores, I/O cores, memory cores, and embedded programmable logic device cores.

"Semiconducto r intellectual property is the cornerstone of the SLI/SoC market."

-- Brian Lewis

DESIGN SERVICES

As SoC pushes for more complete design integration, design firms will be forced to integrate the design process.

Design services are currently experiencing a paradigm shift. Like much of the rest of the high tech world, SoC related design services are being forced to break down design silos and work in interdisciplinary teams. The very nature of SoC is to integrate all functional aspects of a system into one chip. In the past, the design for each functional piece of a system was done by individuals who worked largely independent of others working on the remaining functional components of the same system. As SoC pushes for more complete design integration, design firms will be forced to integrate the design process.

The following description of the emerging SoC design methodologies was paraphrased from an article written by Lauren Brust called “New Methodologies Drive First-Pass SoC Success.”[25]

The design flow for today's SoC first defines the chip at the behavioral level, then separates it into its software and hardware components (Figure 1). The design then passes down independent paths for either software or circuit development, which includes functional design and verification, gate- and circuit-level implementation, and physical layout. Separate design teams most often handle each stage of the design process, with paper specifications handed from one team to the next along the way. Another team unites the hardware and software designs at the end of the process, to take them into prototype. While this methodology has worked well for ASIC designs, it faces severe limitations when used for SoCs. Codesign, in which hardware and software components are designed concurrently, is becoming a priority. The proliferation of point tools has increased the need for industry standards; similarly, intellectual property (IP) also needs greater standardization and documentation.

The traditional design flow moves in a primarily linear sequence, with the software and hardware sides separating at the behavioral level and not integrating until the physical level, often leading to a large number of iterations.

The common practice in today's design process forwards paper specifications to two design teams: one responsible for functional design of the hardware, and the other for the software development. In leading-edge designs, the divisions between the hardware and software pieces of the chip are growing hazier as the pieces become more tightly integrated (Figure 2). The redesigned SoC flow focuses on the need for communication and codesign at every step of the process, resulting in much tighter integration and thus fewer iterations. Once the design work is complete, the total system is verified.

The redesigned SoC flow focuses on the need for communication and codesign at every step of the process, resulting in much tighter integration and thus fewer iterations

To ensure the best time to market and the least flawed design, new methodologies for interdisciplinary teamwork are being developed at Universities local to Utah. The Interdisciplinary Product Development (IPD) program at BYU, a joint Masters Degree between the College of Engineering and the Marriott Business School, has been successful at turning out engineers that not only understand the need for cross-functional teams, but also know how to manage them. Mike Wirthlin at BYU is currently doing research to better develop SoC specific Codesign techniques. His research is discussed in greater detail in The Academic Research section of this document.

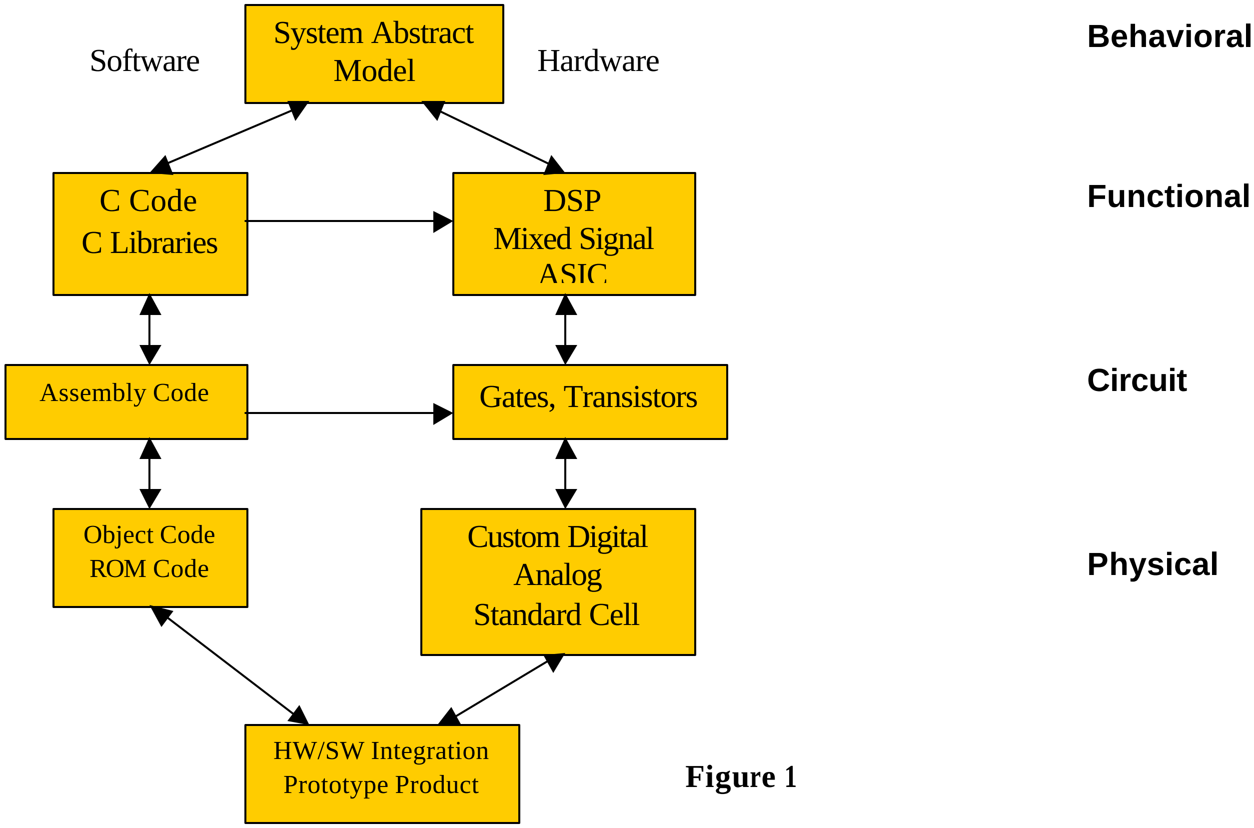


Figure 1

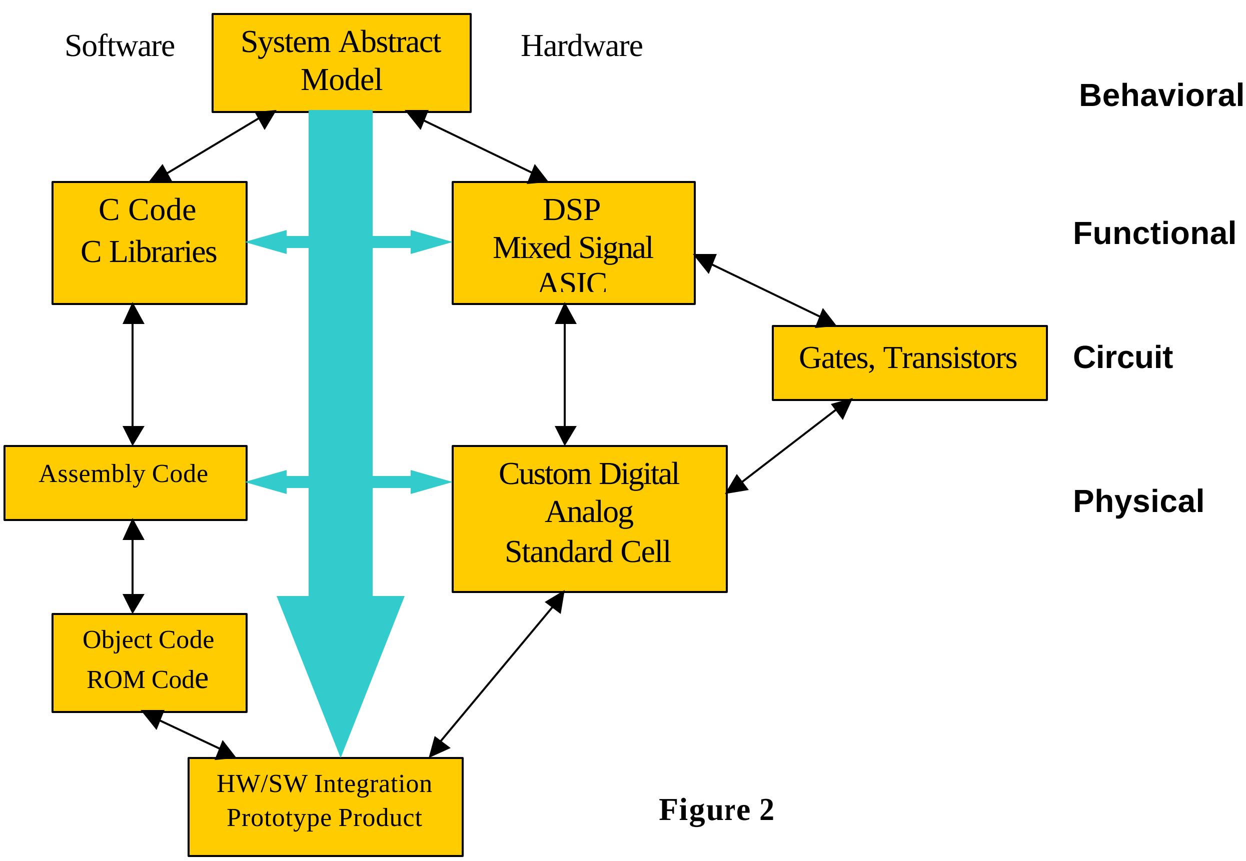


Figure 2

SoC Design Barriers & Design Reuse Strategy

Increasingly, the complex SoC market specializes in consumer applications—cellular phones, DVD players and inexpensive PCs. Consumer markets demand short product life cycles, elusive consumer preferences, and product design cycles with unyielding deadlines. Consumers will continue to demand new features and lower prices, and this can only mean that SoC will become relentlessly more complex and expensive to build. Design reuse on a grand scale is what it's going to take to succeed in this extremely competitive market segment. Indeed, it's the only viable way to solve the problem.

With the advent of SoC design, it has become imperative to reuse many of the functional components stored on an IC for other products.

Design reuse- when intellectual property originally designed for one product is used as part of other products- allows companies to amortize otherwise prohibitive R&D costs across a broadened range of products and applications. With the advent of SoC design, it has become imperative to reuse many of the functional components stored on an IC for other products, integrating new features.

The need for design reuse in the age of highly complex chips appears desirable, if not absolutely essential, for two, unavoidable facts: 1) designing everything from scratch becomes an impossibility every time the complexity of a design exceeds the time allotted to design it; and 2) the in-house expertise or the IP is not always easy to come by.

The combination of technology and more engineering headcount has always yielded incremental productivity improvements in the past, but when the magnitude of the problem is 10x where we already are today, incremental progress is entirely insufficient. That, coupled with the realities of not having the IP available to implement complex chip design, all point to a compelling need for design reuse.[26] While most of the major semiconductor companies have already adopted the design reuse model, there will certainly be winners and losers depending on how well any given firm can implement this strategy.[27]

SoC firms that specialize in design must carefully cultivate partnerships with companies that have sufficient "complimentary assets" such as marketing and distribution power.

Despite the supposed existence of "first mover" advantages, first-to-market innovators with new products and processes do not always win. Situations where firms were first to commercialize a new product, but did not participate in the profits that were subsequently generated from the innovation, are increasingly common. For instance, transistors, integrated circuits, video recorders, and color television are among the many advances made in the West and first embodied in the new products in the West. "Yet in each of these areas the Japanese have subsequently gained a strong and sometimes dominant position."[28] SoC firms that specialize in design, therefore, must carefully cultivate partnerships with companies that have sufficient "complimentary assets" such as marketing and distribution power.

BRANDING IN THE SOC INDUSTRY

Branding within the SoC industry does not play a critical role in the success of a company, but rather emerges as a company captures design wins and market share. In this business to business industry, certain companies may have a bias towards which company's chips are used, but even this bias is generally based on the past performance and reliability of a supplier's product. A brand name is thus earned through experience and quality.

ENVIRONMENTAL ISSUES OF THE SOC INDUSTRY [29]

Semiconductor Manufacturing Process: Many chemicals and other toxic agents are used in the production of semiconductors. Below is a step-by-step listing of all the waste chemicals and agents used in the production of a semiconductor. Naturally, these would be the same wastes that would be associated with any SoC production process.

Step One (Design): This step is comprised of EDA tools, IP providers and design services. There are no environmental considerations in any of the processes associated with design.

Step Two (Crystal Processing): Wastes including antimony, arsenic, phosphorus, and boron may be generated in the wastewater as a result of ion implantation or diffusion. Excess dopant gases, contaminated carrier gases, and out-gassed dopant gases from semiconductor materials may also be generated. Acid fumes and organic solvent vapors may be released during cleaning, etching, resist drying, developing, and resist stripping operations. Hydrogen chloride vapors may also be released during the etching process.

Step Three (Wafer Fabrication): Wastes that may be generated from this process include: organic solvent vapors from cleaning gases; rinsewaters with organic solvents from cleaning operations; spent solvents (including F003); and spent acids and solvents in the wastewater. Wastes that may be generated from these processes include: acid fumes from etching operations; organic solvent vapors from cleaning resist drying, developing, and resist stripping; hydrogen chloride vapors from etching; rinsewaters containing acids and organic solvents from cleaning, developing, etching, and resist stripping processes; rinsewaters from aqueous developing systems; spent etchant solutions; spent solvents (including F003) and spent acid baths.

Step Four (Final Layering and Cleaning): Wastes generated include: acid fumes and organic solvent vapors from cleaning, etching, resist drying, developing, and resist stripping; liquid organic waste; aqueous metals; and wastewaters contaminated with spent cleaning solutions. Wastes generated from these processes include: spent solvents and acids in the wastewater and rinsewater from cleaning, developing, etching, resist stripping, and rinsing processes; acid fumes and organic solvent vapors from cleaning, rinsing, resist drying, developing, and resist stripping; spent silicon dioxide or nitride; hydrogen chloride vapors from etching; rinsewaters from aqueous developing systems; spent etchant solutions; spent acid baths; and spent solvents.

Step Five (Assembly): Wastes generated during punching or etching may include: spent organic vapors generated from cleaning, resist drying, developing, and resist stripping; spent cleaning solutions; rinsewaters contaminated with organic solvents; and spent aqueous developing solutions. Waste generated during these steps includes excess epoxy/thermoset plastic; antimony trioxide (from the molding process); and spent organic solvents.

INDUSTRY SPECIFIC REQUIREMENTS

Below is a list of Acts with which all manufacturers must comply. All waste materials associated with a semiconductor foundry must be handled in compliance to these government regulations.

Clean Air Act (CAA): Under the CAA, the National Ambient Air Quality Standards (NAAQS) have been established for six pollutants. The only one that significantly impacts the electronics/computer industry is the standard for ozone. While the electronics/computer industry is not a major source of ozone, it is a major source of volatile organic compounds (VOC).

Clean Water Act (CWA): The National Pollution Discharge Elimination System (NPDES) permit program regulates the discharge of pollutants to the waters of the United States. A permit is required if a source discharges directly to surface waters. Facilities must provide the results of biological toxicity tests and any information on its "effluent characteristics. The electronics/computer industry must test for all 126 priority pollutants listed in 40 CFR 122, Appendix D. Facilities must provide quantifiable data only for discharges of priority pollutants which the applicant knows or has reason to believe will be greater than trace amounts. Priority pollutants likely to be discharged by facilities in the electronics/computer industry include copper, lead, lead compounds, silver, chromium, and trichloroethylene. Quantitative testing is required for non-conventional pollutants if they are expected to be present in discharges. Examples of hazardous substances and non-conventional pollutants likely to be discharged by the electronics/computer industry include butyl acetate, xylene, formaldehyde, tin-total, nitrate/nitrites, titanium-total, and chlorine-total residual.

Hazardous Wastes Relevant to the Electronics/Computer Industry

EPA Hazardous Waste No.	Hazardous Waste
D006 (cadmium) D007 (chromium) D008 (lead) D011 (silver)	Wastes that are hazardous due to the characteristic of toxicity for each of the constituents.
F001	Halogenated solvents used in degreasing: tetrachloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; all spent solvent mixtures/blends used in degreasing containing, before use, a total of 10 percent or more (by volume) of one or more of the above halogenated solvents or those solvents listed in F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F002	Spent halogenated solvents; tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, ortho-dichlorobenzene, trichlorofluoromethane, and 1,1,2-trichloroethane; all spent solvent mixtures/blends containing, before use, one or more of the above halogenated solvents or those listed in F001, F004, F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F003	Spent non-halogenated solvents: xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol; all spent solvent mixtures/blends containing, before use, only the above spent non-halogenated solvents; and all spent solvent mixtures/blends containing, before use, one or more of the above non-halogenated solvents, and, a total of 10% or more (by volume) of one of those solvents listed in F001, F002, F004, F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F004	Spent non-halogenated solvents: cresols and cresylic acid, and nitrobenzene; all spent solvent mixtures/blends containing, before use, a total of 10% or more (by volume) of one or more of the above non-halogenated solvents or those solvents listed in F001, F002, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F005	Spent non-halogenated solvents: toluene, methyl ethyl ketone, carbon disulfide, isobutanol, pyridine, benzene, 2-ethoxyethanol, and 2-nitropropane; all spent solvent mixtures/blends containing, before use, a total of 10% or more (by volume) of one or more of the above non-halogenated solvents or those solvents listed in F001, F002, or F004; and still bottoms from the recovery of these spent solvents and spent solvents mixtures.

F006	Wastewater treatment sludges from electroplating operations except from the following processes: (1) sulfuric acid anodizing of aluminum; (2) tin plating on carbon steel; (3) zinc plating (segregated basis) on carbon steel; (4) aluminum or zinc-aluminum plating on carbon steel; (5) cleaning/stripping associated with tin, zinc, and aluminum plating on carbon steel; and (6) chemical etching and milling of aluminum.
F007	Spent cyanide plating bath solutions from electroplating operations.
F008	Plating bath residues from the bottom of plating baths from electroplating operations where cyanides are used in the process.
F009	Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process.

Source: Based on 1994 Sustainable Industry: Promoting Strategic Environmental Protection in the Industrial Sector, Phase 1 Report.

OCCUPATIONAL EMPLOYMENT AND WAGE ESTIMATES (1999 NATIONAL)[30]

The following is a partial list of jobs found within the SoC industry. These jobs are more closely related to design than they are to any other link in the value chain.

Computer and Information Scientists, Research

Conduct research into fundamental computer and information science as theorists, designers, or inventors. Solve or develop solutions to problems in the field of computer hardware and software.

Employment estimate and mean wage estimates for this occupation:

Employment	26,280
Mean hourly wage	$32.30
Mean annual wage	$67,180

Percentile wage estimates for this occupation:

Percentile	10%	25%	50% (Median)	75%	90%
Hourly Wage	$19.15	$24.97	$31.38	$39.20	$48.52
Annual Wage	$39,840	$51,930	$65,270	$81,540	$100,910

Computer Software Engineers, Systems Software

Research, design, develop, and test operating systems-level software, compilers, and network distribution software for medical, industrial, military, communications, aerospace, business, scientific, and general computing applications. Set operational specifications and formulate and analyze software requirements. Apply principles and techniques of computer science, engineering, and mathematical analysis.

Employment estimate and mean wage estimates for this occupation:

Employment	209,030
Mean hourly wage	$31.84
Mean annual wage	$66,230

Percentile wage estimates for this occupation:

Percentile	10%	25%	50% (Median)	75%	90%
Hourly Wage	$19.41	$24.32	$31.07	$39.07	$46.63
Annual Wage	$40,360	$50,590	$64,620	$81,260	$96,990

Computer Software Engineers, Applications

Develop, create, and modify general computer applications software or specialized utility programs. Analyze user needs and develop software solutions. Design software or customize software for client use with the aim of optimizing operational efficiency. May analyze and design databases within an application area, working individually or coordinating database development as part of a team.

Employment estimate and mean wage estimates for this occupation:

Employment	287,600
Mean hourly wage	$31.62
Mean annual wage	$65,780

Percentile wage estimates for this occupation:

Percentile	10%	25%	50% (Median)	75%	90%
Hourly Wage	$19.14	$23.98	$30.45	$38.56	$47.58
Annual Wage	$39,800	$49,880	$63,330	$80,210	$98,980

Semiconductor Processors

Perform any or all of the following functions in the manufacture of electronic semiconductors: load semiconductor material into furnace; saw formed ingots into segments; load individual segment into crystal growing chamber and monitor controls; locate crystal axis in ingot using x-ray equipment and saw ingots into wafers; clean, polish, and load wafers into series of special purpose furnaces, chemical baths, and equipment used to form circuitry and change conductive properties.

Employment estimate and mean wage estimates for this occupation:

Employment	42,110
Mean hourly wage	$13.24
Mean annual wage	$27,540

Percentile wage estimates for this occupation:

Percentile	10%	25%	50% (Median)	75%	90%
Hourly Wage	$8.97	$10.20	$12.45	$15.21	$19.13
Annual Wage	$18,670	$21,210	$25,890	$31,650	$39,800

Computer Hardware Engineers

Research, design, develop, and test computer or computer-related equipment for commercial, industrial, military, or scientific use. May supervise the manufacturing and installation of computer or computer-related equipment and components.

Employment estimate and mean wage estimates for this occupation:

Employment	60,420
Mean hourly wage	$32.19
Mean annual wage	$66,960

Percentile wage estimates for this occupation:

Percentile	10%	25%	50% (Median)	75%	90%
Hourly Wage	$19.62	$24.56	$31.12	$39.37	$48.63
Annual Wage	$40,800	$51,070	$64,730	$81,890	$101,140

Electrical Engineers

Design, develop, test, or supervise the manufacturing and installation of electrical equipment, components, or systems for commercial, industrial, military, or scientific use.

Employment estimate and mean wage estimates for this occupation:

Employment	149,210
Mean hourly wage	$29.58
Mean annual wage	$61,520

Percentile wage estimates for this occupation:

Percentile	10%	25%	50% (Median)	75%	90%
Hourly Wage	$18.37	$23.22	$29.15	$35.63	$42.27
Annual Wage	$38,220	$48,310	$60,640	$74,110	$87,920

Physicists

Conduct research into the phases of physical phenomena, develop theories and laws on the basis of observation and experiments, and devise methods to apply laws and theories to industry and other fields.

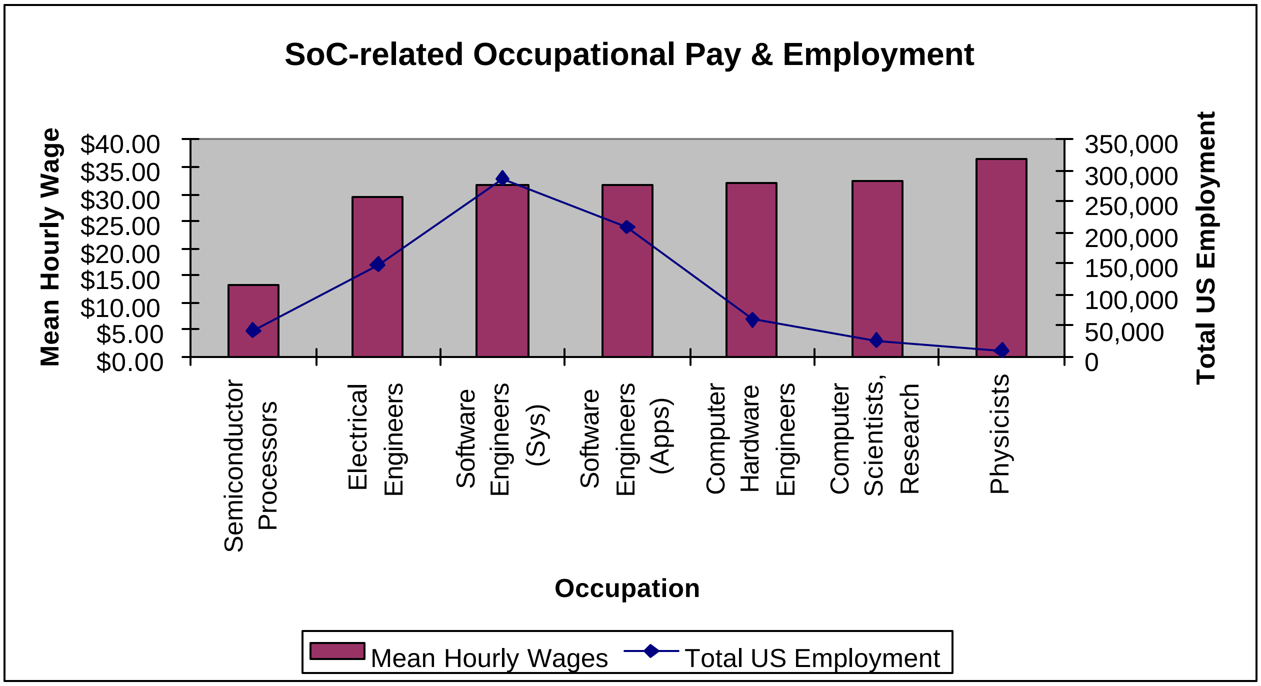
Employment estimate and mean wage estimates for this occupation:

Employment	10,290
Mean hourly wage	$36.61
Mean annual wage	$76,140

Percentile wage estimates for this occupation:

Percentile	10%	25%	50% (Median)	75%	90%
Hourly Wage	$22.72	$29.63	$36.63	$43.63	$52.84
Annual Wage	$47,260	$61,620	$76,180	$90,750	$109,920

Wage Data Analysis



When examining the wage data listed above it is easy to see which jobs are the most desirable to have within the state. For example, a semiconductor processor job is not as desirable as an applications or systems software engineer because the latter two jobs have higher average annual pay than does the former. In addition, there are more jobs available for systems and applications software engineers than there are semiconductor processor jobs. With companies like Novell currently in Utah, there is already a rich job market that exists within the state for software engineers. Because of this, SoC companies that choose to relocate here will have a large base from which to draw software engineers. In addition, the software engineers of SoC companies within the state will have many other job opportunities within the state in the event they would need to change companies.

The above list is not exhaustive of the jobs available in the SoC industry, but provides a general sense of the highest paying segments in the industry. For this reason the design & IP segment of SoC, largely made up of software and hardware engineers, is an attractive segment for the State of Utah. As can be seen in the above chart, these positions make a rough average of $30 per hour (approximately $60,000 a year), as compared to about $13 per hour for processors.

SEGMENTATION

> ***"The convergence of communications, computers and consumer electronics is driving the need for SoC."***
>
> ***-- Michael C. Chang***

SoC has been called the hottest technology trend in the semiconductor industry since the microprocessor.[31] Consumers' unquenchable demand for wireless communication, digital entertainment and broadband access is driving the SoC market.[32] As a result, technology companies are migrating towards smaller, less expensive devices that are higher quality and have more functionality than traditional solutions, further fueling the demand for SoC products. The enormous growth potential that characterizes the SoC industry is summarized by the following analyst projections:

- According to Frost & Sullivan, the SoC industry generated revenues of nearly $2 billion in 2000, a 153 % increase over 1999. Frost & Sullivan projects this market to experience explosive growth in the next few years, generating over $7.5 billion in revenues by 2003.[33]

- In-Stat predicts that SoC volumes will grow an average of 31% a year, reaching 1.3 billion units in 2004. In 1999, SOC shipments jumped 116% to 345 million units from 160 million in 1998. About 39% of the SoC devices served communications systems applications last year.

Time-to-market pressures and the need for more functions in system products are fueling the SoC growth.[34]

> ***Widespread convergence of entertainment, telephony and computerized information comprise the sweet spot of the SoC market and the area that has the most growth potential for the SoC industry.***

The convergence of communications, computer, and consumer electronic technologies is a paramount force behind the escalating demand for SoC related products as multiple complex functions are combined into smaller and smaller electronic devices. This can be demonstrated by the fact that today SoC already accounts for 20% of the billion-dollar semiconductor market, and it is projected that this figure will grow to 60% within the next five years.[35] Widespread convergence of entertainment, telephony and computerized information: data, voice and video, delivered to a rapidly-evolving array of Internet appliances, PDAs, wireless devices (including cellular telephones) and desktop computers, comprise the sweet spot of the SoC market and the area that has the most growth potential for the SoC industry.[36]

The underlying premise of convergence is simple, one network for everything: voice, video, machine-to-machine signaling, remote procedure calls, client/server transactions, document transfer, and a myriad of other functions. Essentially, convergence seeks to maximize the Internet to talk, collaborate, view at a distance, signal, message, notify, broadcast, and share information dynamically. The technology change required by this evolving communications convergence is intrinsically disruptive: to business models, business process, best practice-all the rules and lines-in-the-sand that define and constrain and modulate economic relationships.[37]

According to a report by Plunkett Research, entitled "Computers, Software and Information Technology Trends & Market Analysis," the impending Convergence Age may be characterized by two attributes:

1. Always focused on the nature of the Internet.
2. Complete integration of information and media of all types, with Internet appliances of as-yet undreamed of natures continuously talking to each other.[38]

Prominent SoC providers are becoming major players as the need to aggregate multiple complex functions into smaller devices becomes imminent to competing successfully within the emerging industry of convergence.

The numbers surrounding communications convergence are bigger and more compelling than anything the Internet has seen, so far. Global switched telecommunications is big business: $80 trillion a year in cash flow, according to Piper Jaffrey. Over the next ten years, communications convergence will progressively turn this business on its ear. Most of this voice traffic will end up on the 'Internet, and will be accounted and paid for differently than it is today. All media - broadcast and cable and print; books and music and movies and theatre - will follow the same course: onto the Internet and paid for in new ways. So will nearly all private enterprise networks, and nearly all business communications and computing infrastructure, applications, and data.[39]

As the evolution of convergence takes form, competition is rising while the lines between telecom, computing, and data networking blur. Prominent SoC providers are becoming major players in this arena as the need to aggregate multiple complex functions into smaller devices becomes imminent to competing successfully within the emerging industry of convergence. Recognizing this, a number of industry leaders have also established SoC divisions within their own respective organizations including: IBM, Toshiba and Hitachi within the computer and peripherals industry; Broadcom, Lucent and Motorola in the communications industry; and NEC Electronics, Sharp and Texas Instruments in the consumer electronics industry.[40]

As SoC adoption ensues, there are a number of advantages to the SoC approach. Fewer components can mean improved reliability, simpler logistics, and lower assembly cost. There are also a number of hurdles preventing many more systems designers from going the SoC route. While time-to-market becomes an increasingly important factor for success, more complexity means longer development times, and huge investments are required, including extensive engineering efforts with high-level skills. Further, since more process steps are involved, there can be yield problems, and there is less flexibility in design.[41]

INDUSTRY BREAKDOWN

According to Gartner Dataquest Chief Analyst Tom Starnes, there are over 250 established companies that are chip vendors, 100 or more companies involved in fabrication equipment and materials, and numerous companies that reside in the software and services sector. Furthermore, there are countless, most likely thousands, of start-ups in the SoC space.

SoC companies in the Communications, Computer, and Consumer segments comprise over 80% of the SoC industry.

There are two approaches that may be taken in segmenting the developing SoC industry:

- Grouping by industries served
- Grouping by functions performed (Value Chain)

In both cases a lot of overlap exists. Companies serving multiple industries and/or performing multiple functions, as is commonly characterized by high-growth industries that are still taking shape, are demonstrated in the SoC industry. For purposes of selecting and recommending a number of key SoC anchor companies and promising start-ups, segmentation was performed according to both approaches.

For the industries served segmentation, based on the following market share by segment study performed by Cahners In-Stat Group, SoC companies were grouped according to customer focus in the following categories:

Market Shares by Segment

Communications	38.5%
Computer	26.6%
Consumer	15.0%
Transportation	10.5%
Other	4.6%
Industrial	3.7%
Mil-Aero	1.1%

SOURCE: Cahner's In-Stat Group[42]

The communications market is where the action is in the semiconductor market.

SoC companies in the Communications, Computer, and Consumer segments were selected as areas in which to identify target companies, since together these segments comprise over 80% of the SoC industry. As can be seen, SoC technologies are particularly useful for communications applications: the sweet spot of the semiconductor industry. The communications market is where the action is in the semiconductor industry. It is in this market space where SoC technology is likely to have the greatest disruptive impact.[43]

For the functions performed segmentation, SoC companies were grouped according to the following core activities:

- Design & Intellectual Property
- Manufacturing & Production
- Testing & Verification

Although this model doesn't exactly follow the value chain model, these groupings were chosen because these links are closely tied together in current industry practice.

As the segmentation process advanced, it became evident that segmentation by industries served would most accurately depict industry landscape and leadership. However, the Design & Intellectual Property segment from the function segmentation is comprised of a significant number of design firms that transcend the industries served segments and therefore could not be pigeonholed into individual categories. Further, the incredible innovation and growth-potential of this segment and its indispensable role in the SoC value chain, merited including the Design & Intellectual Property segment when selecting SoC companies that Utah should strategically target in building an SoC base within the state.

Attracting all links in the value chain, not just the design segment, should be the eventual goal of the state. But because Utah currently has a presence in manufacturing and analysts are predicting excess capacity by mid-2001[44], a focus on companies that participate either in all links of the value chain or specifically focus on design may be more attractive in the near future.

SoC Industry Leadership

According to Gartner Dataquest Chief Analyst Tom Starnes, leadership in the system-on-a-chip industry may be characterized according to performance in the following competencies:

- Customer relationships
- Quality of service
- Keen insight
- Strategic execution
- Product features
- Partnerships formed

SOURCE: Tom Starnes[45]

Based on company size, along with the criteria listed above, the following companies have been identified as leaders in their respective industries:

- Communications: Broadcom, inSilicon, Motorola, Lucent, PMC Sierra, and Ciena
- Computer: IBM Microelectronics, LSI Logic, Toshiba, and 3DSP.
- Consumer: Cadence Design Systems, Matsushita, NEC Electronics, Samsung, Sharp, Texas Instruments, and Toshiba.
- Design & Intellectual Property: Cascade Design Systems, Avant!, Synopsys, ARM, MIPS, inSilicon, (all which have revenues that fall in the $500 million to $1 billion range [46])
- Manufacturing & Production: Taiwan Semiconductor, National Semiconductor, Micron
- Testing & Verification: Mentor Graphics, Synopsys, Teradyne, LTX, inSilicon

SOURCE: Chuck Small [47]
Mary Ann Murphy [48]
Jeff Dionne [49]
Jauher Zaidi [50]

COMMUNICATIONS SEGMENT

Although consumer products will have the fastest growth in the market over the next several years, averaging an increase of 43% per year through 2004, communications systems will remain the largest applications driver, consuming 576 million units in 2004, compared to 310 million units in the consumer segment, according to Cahners In-Stat Group. [51]

Leading the communications segment are chipmakers Broadcom and PMC-Sierra, which should see 66% and 86% revenue growth, respectively, due to continued high demand for networking and communications equipment, according to Merrill Lynch. Promising start-up companies in the communications sector include ComSilica, CPU Technology, Palmchip, RealChip, Tality and Triscend.[52]

Communications products are the largest market segment for SoC designs, comprising 38.5% of the total SoC market.

The communications segment of the SoC industry may be subdivided into three categories: telecommunications, data communications, and wireless communications. The following chart provides some general revenue indicators, projected to 2002 on a global scale, for the telecom market as a whole and broken down for telecom services and telecom services expenditures.

Telecommunications Industry Statistics

Key Indicators for the World Telecommunication Service Sector

US$ billions	1990	1991	1992	1993	1994	1995	1996	1997	1998	*2000*	*2002*
Telecom market revenue (current prices and exchange rates)											
Services	396	419	461	491	530	615	673	702	744	*840*	*925*
Equipment	112	119	132	138	161	182	213	237	260	*320*	*375*
Total	**508**	**539**	**593**	**630**	**691**	**797**	**885**	**939**	**1'004**	***1'160***	***1'300***
Telecom services revenue breakdown (current prices and exchange rates)											
Telephone[1]	356	373	394	410	444	497	508	500	500	*460*	*410*
-International[2]	33	37	43	46	47	53	53	54	56	*60*	*60*
Mobile	11	15	23	33	47	75	104	129	154	*230*	*315*
Other [3]	29	31	44	48	39	43	61	73	90	*150*	*200*
Telecom services capital expenditure (current prices and exchange rates)											
Total[4]	115	124	131	134	138	155	166	161	167	*175*	*180*

Notes: All data in millions of current US$ converted by annual average exchange rates. Country fiscal year data aggregated to obtain calendar year estimates.

[1] Revenue from installation, subscription and local, trunk and international call charges for fixed telephone service.

[2] Retail revenue.

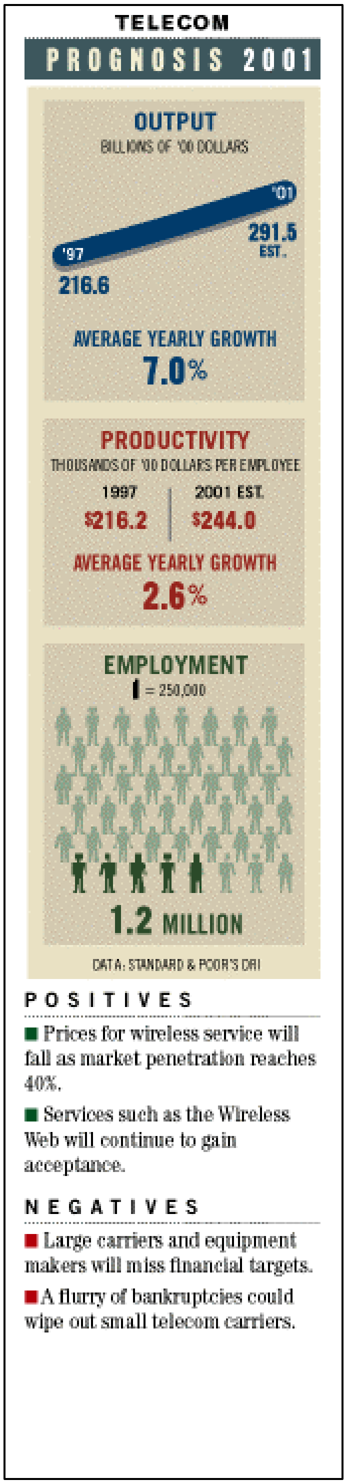
[3] Including leased circuits, data communications, telex, telegraph and other telecom-related revenue.

[4] Note that the data of the growing number of new market entrants are not always reflected in national statistics.

Telecommunications

Telecommunications is a prominent and steadily growing industry that SoC providers can capitalize on. Approximately $200 billion is spent in the U. S. each year, $50 billion for long-distance calls, on voice telephone, representing a huge opportunity for SoC companies targeting the communications sector. Growth exhibited in the telecommunications sector has occurred at a solid and steady pace:

Telecommunications is a prominent and steadily growing industry that SoC providers can capitalize



- Interstate voice traffic (which carries some fax and modem data) has been recently growing about 8% a year, up from the 4% rates of the early 1990s, when measured in minutes of use.
- At the end of 1997, U. S. carriers had about 40 billion voice minutes per month of interstate traffic on their public networks, according to the Federal Communications Commission.
- Capacity and presumably traffic on private line networks have been growing 15% to 20% per year in the last few years.[53]

As companies in this industry advance and make efforts to fend off fierce competition, both within this sector and outside from competing technologies like Internet telephony and data communications tools like email, they will be constantly seeking new avenues for innovation, leadership, and ultimately, profitability. SoC technology can play a key role in this process, enabling telecom companies to integrate leading-edge chip technology that expands the functionality and utility of their devices, ultimately maintaining a competitive edge within their sector and encroaching into competing sectors with multi-functional devices. In this light, telecom companies such as Lucent have established divisions aimed at SoC development and released SoC related products.

Data Communications

The data communications sector is best articulated by the two categories that drive activity within this space: Internet capability and the networking and bandwidth technologies that enable the Internet itself. Data communications is an exploding market, growing at Internet speed. The capabilities that SoC technologies offer are particularly applicable to this market, as devices are becoming smaller, more portable and multi-functional, making SoC poised for success in this area.

The capabilities that SoC technologies offer are particularly applicable to the data communications market, as devices are becoming smaller, more portable and multi-functional.

The Internet

One of the most substantial areas of growth in the communications industry is the Internet. By the end of 1999, over 200 million people were online worldwide. Of those users, 118 million alone were in the U.S. According to a report entitled "The Size and Growth Rate of the Internet," released by First Monday, Internet traffic is currently growing at a rate of 100% per year and the Internet sector is far from the saturation point; it is projected that the number of users worldwide will approach 500 million in the next few years.[54, 55]

Currently, while over 95% of U.S. homes have telephones, only a little over 50% of those households have personal computers, and only slightly more than 50% of those with home computers have Internet access, presenting a tremendous opportunity for growth not only within the industry, but also for supporting companies like SoC providers. Further, as PC prices continue to drop and the Internet continues to evolve into an entity that the general user finds attractive, the number of people online will continue to soar, spurring greater growth in data communications and thus, the SoC companies that support this sector.[56]

Networking Equipment

Networking equipment and bandwidth technologies is another area that dramatically impacts the data communications market. The rate with which the data communications market grows is largely contingent upon the amount of bandwidth in place and the networking equipment in place to support that bandwidth. To this extent, according to Cahners In-Stat Group, the worldwide networking equipment market grew to $11.8 billion in Q2 2000, a healthy 8 % increase from Q1 2000. Further, the networking equipment market is positioned for more robust growth in the near future. Specifically, DSL and cable modem sales and projected growth are as follows:

- DSL and cable modem revenues combined, increased 30 percent.

- The number of consumer cable modem and DSL access subscribers will grow 77 percent between 1999 and 2004. Subscriber revenues from these two services will also grow from just over $1 billion U.S. in 1999 to $13.3 billion U.S. by 2004.

SOURCE: Cahners [57]

In the chip sector, the smart home networking IC market will experience aggressive growth, growing from a mere $41 million in 2000 to over $650 million in 2005.

According to Cahners In-Stat Industry Analyst Daryl Schoolar, "The biggest broadband consumer application is home networking, with 33% of broadband users using that function." In the chip sector, the smart home networking IC market will experience aggressive growth, growing from a mere $41 million in 2000 to over $650 million in 2005. Further, revenues for smart home networking chips in the US are expected to grow at a compounded annual growth rate of 77% through 2005, displaying huge growth and profit potential for SoC companies that are positioned to serve this sector.[58, 59]

Wireless Communications

Wireless providers represent the fastest growing segment of the communications industry.

- Larry Kraft, VP of marketing for ASC

In 1999, close to 220 million people worldwide owned wireless phones. According to Plunkett Research, that number is projected to grow to nearly one billion within five years. Currently, approximately 30% of the U.S. population have cell phones, but estimates released by Strategy Analytics suggest that there will be 80% penetration of the U.S. cellular market by 2005. Additionally, expenditures on "third generation" wireless services and equipment, which transport data at up to two megabits per second, alone are expected to reach $100 billion by 2007.[60, 61]

However, according to BusinessWeek's Industry Outlook report on Telecommunications, wireless revenue growth, though still strong, will slow this year. While in 2000, this global industry soared 50% to $128.9 billion, in 2001 this figure is expected to drop to around 23%. [62]

SoC technology is increasingly playing a larger role in the wireless arena as wireless devices are progressively becoming smaller and more portable, resulting in chip sets being shrunk down into a single chip. Motorola, a major player in the wireless device space, is just one company that understands the benefit of SoC technology to the wireless industry and has worked to develop some of its own SoC solutions.

CONSUMER ELECTRONICS SEGMENT

Over the next several years, the consumer products segment will grow faster than any other in the market, averaging an increase of 43 percent per year through 2004.

Over the next several years, the consumer products segment will grow faster than any other in the market, averaging an increase of 43% per year through 2004. A large part of this growth is due to a proliferation of "converged" devices including Internet appliances, PDAs, multi-functional cell phones, digital cameras, spurred on by an industry wide migration towards the convergence of communications, computers, and consumer electronics. According to *BusinessWeek*'s Industry Outlook report on computers and chips, a number of the resulting newly created niches should continue to expand at a rate of 20% or more. Further, the niches' consumer devices should get a lift as prices come down and features proliferate [63]. Growth projections for the consumer electronics market include:

- Information-appliance sales will soar to $17.8 billion, or 89 million units, in 2004, compared to $2.4 billion or 11 million units, in 1999.[64]

- The residential gateway market will see sales rise sharply from $100 million in 2000 to $5 billion in 2005, presenting lucrative opportunities for electronics equipment and component manufacturers, Cahners In-Stat Group forecasts.[65]

Several major consumer product companies have been migrating to SoC for some of their designs.

Fueled by the evolution to convergence, over the past few years several major consumer product companies have been migrating to SoC for some of their designs. The decision to migrate to this methodology is typically driven by the need for enhanced functionality, reduced power consumption and increased portability. However, one potential hurdle to SoC in this area has occurred over the last five to six years; while the electronics industry has seen a constant reduction in product life cycles, SoC design cycles have incrementally increased to meet the demands of complex new and changing specifications, generally customized for individual applications. Thus, as more and more companies are undertaking SoC design, the quality of the IP blocks must be raised to meet the needs of an ever-evolving industry.[66, 67]

Major applications in the consumer electronics industry include Internet appliances and handheld computers, audio equipment, and digital products.

Internet Appliances, Handheld and Personal Computers

Over the next several years the Internet appliance market will heat up, with sales growing over 40% per year between 2000 and 2005. Further, total Internet appliance sales will jump from $219 million in 2000 to $1.3 billion in 2005. Much of the growth will occur outside of the PC-centric North American and Western European markets. [68, 69]

According to a market analysis report distributed by Plunkett Research, the number of computer-related consumer devices, including Internet access appliances, sold in the United States will surpass the number of traditional PCs in use. While sales expectations for computer-related devices is 18.5 million in 2001, only about 15.7 million home PCs are projected to be sold the same year. The surge in this market will cast ripple effects on components suppliers, fueling chip growth. Semiconductor manufacturers, and thus, SoC technology providers, will find the Internet Appliance market rewarding over the next several years. Cahners In-Stat Group estimates that sales of Internet Appliance microprocessors alone will jump from $18 million in 2000 to $91 million in 2005. Related technologies such as flash and DRAM sales will also experience growth, at 5% and 27% respectively. [70, 71]

The number of computer-related consumer devices, including Internet access appliances, sold in the United States will surpass the number of traditional PCs in use.

Handheld computers are expected to reach a wider audience in 2001, as traditional computer companies including Compaq and Hewlett-Packard enter the market and compete with handheld computing leaders Palm, Casio, and upstart Handspring. Broad exposure in this area will result in expected sales of the devices surging 31%, to 8.7 million units, according to Cahners In-Stat Group. These devices will grow more powerful, spawning a host of peripherals.[72]

The mobile computing device market is also projected to grow to 16.7 million units in 2004, representing an average annual growth rate of 28.0% over a five year forecast period. Further, by 2004, more than 51% of mobile computing devices shipped will be wireless-enabled. Moreover, integrated phone modules, to provide voice capabilities to mobile computing devices, will be a force of change in the market, creating a potential profit pool for SoC contenders. [73, 74]

Audio Equipment

Overall audio sales for 2000 reached $7.2 billion, increasing 9%. In this area, the portable audio sector shows the most aggressive growth over last year, at a rate of 16% with record revenues $2.2 billion with portable compressed audio, MP3-type players, sales totaling $107 billion for approximately 587,000 units. This progressive growth has attracted traditional computer vendors such as Hewlett Packard and Compaq to enter the digital audio sector, enabling them to expand the scope of their businesses from a traditional PC focus and to diversify their product lines.[75]

SoC is positioned at the front of all technology hardware innovation.

SoC is positioned at the front of all technology hardware innovation. Because of the thrust for smaller, faster, and more functional products, SoC stands to profit from the growth in the industries and industry segments of the consumer electronics listed above, proof of the future success of SoC.

Digital Products

Digital televisions and peripheral equipment and digital cameras are major movers within the digital products market. In the first ten months of 2000, nearly 460 thousand digital televisions were shipped domestically, representing over a billion dollars in revenues compared with less than $180 million for the same period of the previous year.[76] Similarly, factory sales of digital cameras through the third quarter of 2000, surpassed total annual sales for 1999, reaching nearly 2.8 million units with no signs of slowing sales.[77]

The rapid proliferation of digital devices that has occurred over the last several years demonstrates a compelling argument for SoC usage in this sector.

The rapid proliferation of digital devices that has occurred over the last several years demonstrates a compelling argument for SoC usage in this sector, as multiple technology applications are converged within these devices to enable digital functionality.

COMPUTER SEGMENT

Until recently, the personal computer market dominated semiconductor demand. However, the convergence evolution has shifted this demand towards consumer electronics, communications infrastructure, and a host of portable business and personal devices. In 2000, worldwide PC shipments totaled 134.7

million units, a 1415% over 1999 shipments. While this growth appears to be quite aggressive, a sluggish fourth quarter, with growth of only 10% worldwide, inhibited growth figures and suggests the beginning of a downward trend.[78]

For 2001, the industry is still poised to grow 16.6%, according to market researcher International Data Corp. However, in light of the fact that PC sales have seen average growth of more than 20% for nearly a decade, this projection is somewhat disconcerting.[79]

According to Charles Smulders, principal analyst of Gartner Dataquest's Computing Platform Worldwide group, "the downturn in growth is concrete evidence that saturation in key segments is playing an increasingly important role in overall market growth, with new shipments unable to mask the effects of economic cycles on placement buying." [80]

Thus, while the computer industry represents a large portion of the total SoC market, 26.6%, future focus will most likely target the communications and consumer electronics industries that are most poised for growth.[81] As a result, many traditional computer companies are looking beyond their traditional boundaries and moving into complimentary industries with higher growth opportunities, typically born out of convergence. Specifically, outside of the traditional desktop PC, there are a number of niches, including laptops, with higher margins that will continue to expand at rates of 20% or better.[82] One notable example is Compaq and Hewlett Packard's expansion into the digital compressed audio space, adding MP3 devices to their product lines.

While the computer industry represents a large portion of the total SoC market, 26.6%, future focus will most likely target the communications and consumer electronics industries that are most poised for growth.

POSITIVES

- It will be a big year for small devices: handheld computers, MP3 music players, and digital cameras.
- Makers of the specialty chips that run those devices should see revenues and profits climb.

NEGATIVES

- The long-term flattening of PC sales will continue.
- Midyear may bring a glut of memory chips and microprocessors.

Source: BusinessWeek[85]

Trends in Computing

The following trends will also significantly influence overall computer industry growth rates.

- Prices for computing hardware (both desktop and portables) will continue to drop, expecting to fuel first time and additional unit purchases, opening up the market for home connectivity.

- Networkability will be the most important market factor across all consumer and business segments for 1999 and 2004.

- Disposability, defined as the ability to effortlessly discard computing devices and quickly acquire a replacement device that will assume previous functionality plus additional features and functions, shows the greatest increase in importance across all segments from 1999 to 2004.

- Handheld devices filter down to the masses. In 2004, mobile workers of all kinds will embrace handheld products. Corporations, realizing the lower cost and increased productivity benefits inherent in these devices, will be more inclined to invest a greater portion of their IT budgets on these smaller, portable devices.

Source: Cahners In-Stat[83]

DESIGN & INTELLECTUAL PROPERTY SEGMENT

Frost & Sullivan projects the high-growth SoC industry will generate over $7.5 billion in revenues by 2003.[84] From a functional perspective, SoC design is a primary driver of the industry at-large, providing essential intellectual property components that create the pattern for building the chips themselves. GartnerGroup

> ***From a functional perspective, SoC design is a primary driver of the industry at-large.***

believes this IP to be the cornerstone of the SoC market and the larger semiconductor market.[86]

SoC devices can be very expensive in part because their design can take much longer than expected. A company's leading edge design may cost $15 to $20 million to develop and take 12 to 16 months to design, while the average product life is only about nine months.[87] The development cycle typically breaks down nicely with 50% of costs attributed to hardware and 50% attributed to software. The following table delineates the progress made in chip design over the last several years, as designers move down the learning curve.

Process Technology Evolution

	1997	1998	1999
Process technology	0.35µ	0.25µ	0.18µ
Cost of fab	$1.5-2.0B	$2.0-3.0B	$3.0-4.0B
Design cycle	18 ‡ 12 mos.	12 ‡ 10 mos.	10 ‡ 8 mos.
Derivative cycle	8 ‡ 6 mos.	6 ‡ 4 mos.	4 ‡ 2 mos.
Silicon complexity	200-500K gates	1-2M gates	4-6M gates
Applications	Cellular, PDAs, DVD	Set-top boxes, wireless PDA	Internet appliance, portable "everything"
Primary IP sources	intragroup	intergroup	intercompany

Source: Cadence web site[88]

The complexity and substantial resource provisions of the design function can pose large hurdles to SoC providers trying to efficiently meet the requirements of a diverse customer base.

"The increased resources and effort required, along with the higher risk associated with today's methodologies, makes it difficult to keep pace with Moore's Law."

--Lauren Brust, Integrated System Design[89]

Time-to-market refuses to be slowed by design delays. Thus, the design sector Electronic Design Automation (EDA) software market is ripe for contenders and start-ups offering more complete tooling solutions.[90] Further, this factor, coupled with significant time and resource requirements, has endorsed a trend of outsourcing complex design functions and cultivated the emerging design services sector, characterized by a few large firms like ARM, Cadence, MIPS, Mentor Graphics, Avant!, and Synopsys, as well as a host of start-up companies including Palmchip, RealChip, Tensilica, and SliceX.

The evolving practice of developing foundational IP cores that can be used as design platforms plays a crucial role in getting an SoC product to market in a timely manner.

In an attempt to minimize development hurdles, the evolving practice of developing foundational IP cores that can be used as design platforms plays a crucial role in getting an SoC product to market in a timely manner. Currently, there are a few standard IP cores that can be utilized but, on the whole, chips must be custom designed for a vast array of applications that pervade the communications, computer, consumer, transportation, industrial, military-aerospace, and other markets. Thus, the functional design segment is very profitable and designers can command a large salary.[91]

Design reuse is a fundamental requirement in the SoC industry for leadership in the near term and survival in the medium to long term.

Presently, the silicon community lacks strong support of IP blocks. Design reuse enables efficient design of complex system-chips by closing the productivity gap that currently pervades the discipline. The transition to SoC is largely contingent upon the incorporation of reuse into the design process to achieve cost-effective silicon use without sacrificing time-to-market.[92] Consequently, design reuse is a fundamental requirement in the SoC industry for leadership in the near term and survival in the medium to long term.[93]

The design paradigm is evolving from a traditional, coherent project team, where designs are jointly developed from a top-down perspective, to multiple independent teams formed to develop entire design blocks, in a project-style format, separated from the chip-integration project by variables of time, context, geography, and sometimes corporate boundaries. Looking down the road, as the SoC industry matures and more standardized IP blocks are developed, patented and licensed, setting a industry norm for design practices, the profitability and growth of the design segment will be further enhanced by more efficient design processes and royalty streams.

SOC IN UTAH

Utah was ranked 6th in the State New Economy Index in 2001[94], a measure of the degree to which a state's economy is able to adapt to the new economic order spurred by advances in information technology. The Salt Lake City Metropolitan region was ranked 9th in the same index for metropolitan areas[95]. These rankings imply that Utah is poised to capitalize on the high growth high-tech industries, including SoC, driving the economy.

Utah's electronics hardware industry consists of approximately 276 companies ranging from high-tech computer peripheral manufacturers to simple lighting equipment manufacturing and assembly. The average electronic hardware company employs less than 50 employees; however approximately five companies within the industry employ more than 500 employees[96].

Although Utah has a significant amount of companies in the hardware industry, very few are intricately involved in the SoC industry. Only four companies were identified as having a significant portion of their core business within the SoC space. But, although small in number and pre-IPO, these companies are growing stronger in their respective segments of the SoC industry.

INARI

11781 S. Lone Peak Parkway
Draper, UT 84020
Tel: (801) 571-4000
Fax: (801) 501-7630
www.inari.com

CEO: Todd Frohnen

Founded in 1997 with headquarters in Draper, Utah, Inari is at the forefront of Powerline innovation and the only company currently shipping high-speed Powerline networking silicon. Inari provides developers rapid market entry with a proven, scalable design solution for Powerline-enabled products. In 2001, Inari shipped its 2 Mbps IPL0201 Powerline chipset to Thomson Multimedia, which developed a Powerline network adapter through its RCA brand. Inari is currently concentrating its efforts on selling its powerline chipsets to modem, gateway and network interface card (NIC) vendors, who will now be able to manufacture powerline-enabled products. Powerline-enabled modems, gateway devices and NICs will not only allow users to share a single Internet connection among multiple PCs, but will also give them the ability to stream multimedia content and control smart devices over the powerline.

In addition, Inari will provide high-speed powerline chipsets to OEM partners in the consumer electronics marketplace, who will embed the powerline chipsets into products such as televisions, VCRs and DVD players making those devices a part of the home network. Inari is also developing a low-cost, low-speed control chip that will integrate home control functionality into the home network as well. Heating/cooling, security and lighting systems employing Inari's control chip will give users remote access and control of these systems via the Internet. Inari designs and manufactures SoC technology and does end consumer product development.[97]

Quick Facts	
Sales (2000)	N/A
Funds Raised	$29M
Major Investors	Nth Power, Schneider Electric, Globespan, Inc.
Credit Rating	N/A
# of Employees	>100
Source: U.S. Business Directory	

LINEO

Corporate Headquarters
390 S. 400 West
Lindon, UT 84042
Tel: 801-426-5001
Fax: 801-426-6166
www.lineo.com

CEO: Bryan Sparks

Lineo, Inc. provides Linux-based embedded systems, real-time and high availability solutions that include software, hardware reference designs and professional services. Lineo's solutions allow OEMs to create devices and systems that interact with the Internet while helping OEMs to reduce system requirements, per-unit costs and time-to-market. The company's key product lines include: Embedix™ (embedded Linux system software), uClinux™ (embedded Linux for MMU-less processors), SecureEdge™ (Linux-based Internet appliances including VPN Internet routers, network attached storage and firewalls), RTXC™ (general purpose and DSP real-time operating system), BeaconSuite™ (x86 development toolkit), RTXC™ Quadros™ (a real-time operating system for multi-processor devices) and Availix™ (mission-critical high availability Linux cluster solutions).

Quick Facts	
Sales (2000)	$5M
Sales Growth (FY 2000)	78.6%
Funds Raised	N/A
Major Investors	The Canopy Group
Credit Rating	Good
# of Employees	330 worldwide ~150 in Utah

Source: Hoover's Company Capsule Database - American Private Companies

Established in the summer of 1998, Lineo has grown rapidly, largely through eight acquisitions, increasing from 12 employees to more than 325 current employees worldwide during the past two and a half years.[98]

SLICEX

1144 West 3300 South
Salt Lake City, UT
84119
Tel: (801) 474-1447
Fax: (801) 474-1450
www.slicex.com

CEO: Tom Wolf

SliceX (Salt Lake Integrated Circuit EXperts) is a privately held, mixed signal design center specializing in analog IP and engineering design solutions that emphasize shorter development cycles and cost reduction. SliceX is a skilled developer of low power ADC, DAC, and PLL mixed-signal blocks for such industries as semiconductor, imaging, consumer, medical, and R&D.

SliceX offers complete silicon solutions from system architecture through custom layout. With expert mask designers and skilled engineers, SliceX facilitates SoC projects with customizable IP, design services, and close customer support.[99]

Quick Facts	
Sales (2000)	N / A
Funds Raised	N / A
Major Investors	Private investors, customer financing
Credit Rating	N / A
# of Employees	~30

Source: U.S. Business Directory

SORENSON TECHNOLOGIES, INC.

1011 West 400 North
Logan, UT 84321
Tel: (435) 792-1100
Fax: (435) 792-1101
www.sorensontech.com

CEO: James L. Sorenson, Jr.

Sorenson Technologies, Inc. (STI) has been designing and developing high quality video communication technology since 1996. Early research focused on discovering better ways to transmit bandwidth constrained video from the space shuttle and satellites to ground stations. In conjunction with Utah State University in Logan, Utah, STI developed industry-leading image compression technologies. These breakthroughs led to real-time video codecs and multimedia software products.

Presently STI's proprietary technologies are embodied in fifteen issued patents and four pending applications. Virtually all of Sorenson's business activities are SoC related. The privately funded company was created on April 10, 2000 when Sorenson Vision was restructured.[100]

Quick Facts	
Sales (2000)	N / A
Funds Raised	N / A
Major Investors	Currently seeking venture capital
Credit Rating	N / A
# of Employees	>100

Source: U.S. Business Directory

Target Companies

Communications
Consumer Electronics
Computers
Design & Intellectual Property

RATIONALE FOR IDENTIFYING TARGET COMPANIES

In order for Utah to become a sustainable SoC hub, a critical mass of companies within the industry must be obtained. Not only will a conglomeration of firms attract other companies within the industry and spur innovation and spin-offs, but it will also help attract a skilled workforce that demands a pool of alternate jobs before relocating. Recognized leaders in identified segments of the semiconductor industry will serve as anchor companies, encouraging the growth of smaller, established companies and start-ups. To serve effectively, these companies must be large enough and profitable enough to weather the downturns in this cyclical industry. Larger companies also have the resources necessary to capture the profits from marketing new products.

In order for Utah to become a sustainable SoC hub, a critical mass of companies within the industry must be obtained.

Among the 15 companies identified as target companies, 10 are large, public firms that would act as anchor companies. These companies' financial performances were impressive compared with the average baseline performance of U.S., Silicon Valley, and Colorado SoC firms (See Appendix 3). Although it may be overly optimistic to assume that these companies will relocate their headquarters to Utah, securing the location of expanding divisions may be feasible. The remaining five recommended companies are established, pre-IPO firms that have tremendous potential for growth and success. Relocation to Utah as opposed to expansion may be a feasible target for these companies. Because Utah's current environment does not support smaller start-ups well, the targeted private companies are more mature and generally are close to or have completed their third round of financing. This will help ensure that they have the ability to continue to thrive in Utah's environment.

COMMUNICATIONS:

AGERE SYSTEMS

Although Agere is brand-new as its own company and is not yet profitable, its Lucent roots and backing make it a strong competitor in the SoC industry and poised for success.

555 Union Blvd.
Allentown, PA 18109
Tel: (610) 712-4323
www.agere.com

CEO: John T. Dickson

- World leader in semiconductors for communications applications
- IPO conducted on March 28, 2001; Lucent has announced its intention to distribute to its stockholders of all of the stock it then owns by September 30, 2001

Agere Systems (AGRa), formerly the Microelectronics division of Lucent Technologies, is the world leader in sales of communications semiconductors. It designs, develops and manufactures components for communications networks, and integrated circuits for use in a broad range of communications and computer equipment. Agere products are sold globally to the leading manufacturers of communications and computer equipment. The company offers integrated optoelectronics and integrated circuits solutions to help customers reduce the time and expense of developing new communications equipment. It also provides wireless computer networking solutions through its ORiNOCO product line.

Performance Measures	
Sales (ttm)	$5.23B
Sales Growth (6mo ended 3/01)	25.58%
Profit Margin (ttm)	-7.3%
Net Income (ttm)	-$383M
Return-on-Assets (ttm)	-5.34%
Total Liabilities	$1.5M
Debt-to-Equity (mrq)	.01
Return-on-Equity (ttm)	-6.58%
Price-to-Earnings	N/A
Market Capitalization	$11.4B
# of Employees	16,500

Source: Yahoo! Finance (AGRa)

Agere offers a broad range of network SoC and optoelctronic components, along with embedded static random access memory (SRAM) architecture that couples higher levels of density and speed with design and manufacturing flexibility for communications SoC.[101]

BROADCOM CORPORATION

With explosive sales growth and a principal role in the communications industry, Broadcom would provide the necessary leadership in promoting the development of an SoC hub in Utah despite the company's current negative ROE.

Corporate Headquarters
16215 Alton Parkway
P.O. Box 57013
Irvine, CA 92619-7013
Tel: (949) 450-8700
Fax: (949) 450-8710
www.broadcom.com

CEO: Henry Nicholas

- Leading provider of highly integrated silicon solutions that enable broadband communications and networking of voice, video and data services
- Sales revenues more than doubled for FYE 2000

Broadcom (BRCM), founded in 1991, is the leading provider of highly integrated silicon solutions that enable broadband digital transmission of voice, video, and data. Using proprietary technologies and advanced design methodologies, the company designs, develops and supplies complete SoC solutions and related applications for a number of the most significant broadband communications markets, including the markets for cable set-top boxes, cable modems, high-speed local, metropolitan and wide area networks, home networking, Voice over Internet Protocol (VoIP), residential broadband gateways, direct broadcast satellite and terrestrial digital broadcast, optical networking, digital subscriber lines (xDSL) and wireless communications.[102]

Performance Measures	
Sales (ttm)	$1.22B
Sales Growth (FYE 2000)	110.30%
Profit Margin (ttm)	-89.2%
Net Income (ttm)	-$1.08B
Return-on-Assets (ttm)	-37.95%
Total Liabilities	$202.6M
Debt-to-Equity (mrq)	.02
Return-on-Equity (ttm)	-40.90%
Price-to-Earnings	N / A
Market Capitalization	$8.65B
# of Employees	2,706

Source: Yahoo! Finance (BRCM)

INSILICON CORPORATION

Targeting high-growth communications applications with its IP solutions, inSilicon performs in the value-added segment of the semiconductor industry, thereby ensuring continued demand for its products and services.

411 East Plumeria Drive
San Jose, CA 95134
Tel: (408) 894-1900
Fax: (408) 570-1230
www.insilicon.com

CEO: Wayne C. Cantwell

- inSilcon products reduce product development costs, improve design reliability, and speed time-to-market for leading-edge FPGA, ASIC, and SoC designs
- Formed as an independent company by Phoenix Technologies on November 1, 1999, conducted IPO on March 22, 2000

inSilicon Corporation (INSN) is a leading provider of communications platforms used by semiconductor and systems companies to design systems-on-a-chip that are critical components of innovative wired and wireless products. inSilicon's technology provides customers faster time-to-market and reduced risk and development cost. The company's broad portfolio of analog and mixed-signal products and enabling communications technologies, including the JVX(TM) and JVXtreme(TM) Java(TM) Accelerators, Bluetooth, Ethernet, USB, PCI, and IEEE-1394, are used in a wide variety of markets encompassing communications, consumer, computing and office automation.[103]

Performance Measures	
Sales (ttm)	$25.6M
Sales Growth (FYE 2000)	34.15%
Profit Margin (ttm)	-8.6%
Net Income (ttm)	-$2.20M
Return-on-Assets (ttm)	-3.34%
Total Liabilities	$3.0M
Debt-to-Equity (mrq)	.04
Return-on-Equity (ttm)	-4.02%
Price-to-Earnings	N / A
Market Capitalization	$50.3M
# of Employees	91

Source: Yahoo! Finance (INSN)

REALCHIP COMMUNICATIONS INC.

Included in the Red Herring 100 for 2001 list, RealChip is well positioned to serve the needs of the communications market with its SoCs for voice, data, and video transportation.

1290 Oakmead Parkway #218
Sunnyvale, CA 94085
Tel: (408) 735-9065
Fax: (408) 735-9081
www.realchip.com

CEO: John Zucker

- Named a Red Herring 100 Company for 2001
- Multiple partners, including Palmchip
- Founded in 1998, pre-IPO

RealChip develops and markets communication SoC to transport voice, data and video over packet-based networks. The company's unique, patent-pending technologies enable key benefits for communications OEMs utilizing its standard and custom chips; unprecedented time-to-market; fast re-targeting of chip products across multiple system end products; unmatched ability to reprogram and upgrade software in the field; highly differentiated communications end products; and lower overall cost and risk. RealChip has a wholly owned subsidiary, RealChip (P) Ltd., as its India Technology Center, designing communications integrated circuits and conducting related research and development efforts in hardware, software, and systems.[104]

Quick Facts	
Sales (2000)	$5M
Funds Raised	$22M
Major Investors	Comstellar Technologies, Inc.
Credit Rating	Satisfactory
# of Employees	95
Source: LEXIS-NEXIS, U.S Business Directory	

TRISCEND CORPORATION

In an industry in which time-to-market is crucial, Triscend's Configurable SoC products offer companies a reduction in development time. As a result, the company is likely to continue to grow and succeed.

301 N. Whisman Rd.
Mountain View, CA
94043-3969
Tel: (650) 968-8668
Fax: (650) 934-9393
www.triscend.com

CEO: Stanley Yang

- First company to ship a CSoC device
- Partnerships with leading companies such as ARM, Cadence, Sharp, and Synopsys
- Founded in 1997, privately held and venture capital funded

Triscend is a fabless communications IC company pioneering a new era in communications semiconductors--the Configurable System-on-Chip (CsoC). Using a CSoC, a communication system designer can instantly create a customized processing platform, which permits extremely rapid time-to-market advantages without sacrificing product differentiation. Triscend is delivering the industry's first CSoC devices, the E5 family, and the companion software development tool, the FastChip™ Development System. Triscend will be producing multiple CSoC families based on leading 8-bit, 32-bit, and DSP processors.[105]

Quick Facts	
Sales (2000)	$2.5-4.9M
Funds Raised	>$40M
Major Investors	Berkeley International VC, Wasserstein Adelson Ventures, Vulcan Ventures
Credit Rating	Satisfactory
# of Employees	N/A
Source: LEXIS-NEXIS, U.S Business Directory	

ZEEVO

Focusing on SoCs for the converging communications and consumer electronics markets and having completed multiple rounds of financing, Zeevo is poised for growth and success.

2500 Condensa Street
Santa Clara, CA 95051
Tel: (408) 982-8000
Fax: (408) 982-8008
www.zeevo.com

CEO: Anil Aggarwal

- Fast growing
- Founded in 1999

Zeevo, Inc. is a privately owned fabless semiconductor company based in Santa Clara, CA. The company was founded in 1999 to develop and market SoC solutions for the communications marketplace. Zeevo's goal, Enabling Pervasive Connectivity(TM), means staying connected anytime, anywhere in order to have a true "Personal Web" that can be carried with you at all times. Zeevo, a member of the Bluetooth SIG since January 2000, has been actively working on the development of Bluetooth technologies for more than a year.[106]

Quick Facts	
Sales (2000)	N / A
Funds Raised	$42M
Major investors	Dell Ventures, Sequoia Capital, Raza Venture Fund
Credit Rating	N / A
# of Employees	N / A

Source: LEXIS-NEXIS, U.S Business Directory

CONSUMER ELECTRONICS:

ARM LIMITED

ARM has emerged as a leading intellectual property provider. Its IP cores are becoming the recognized industry standard for design of consumer electronics.

Corporate HQ
110 Fulbourn Road
Cambridge
CB1 9NJ
England
Tel: (44) 01223 400400
Fax: (44) 01223 400410
www.arm.com

US HQ
750 University Avenue,
Suite 150
Los Gatos, CA 95032
Tel: (408) 579-2200
Fax: (408) 579-1205

CEO: Robin Saxby

- Microprocessor cores becoming a de facto standard in consumer electronics applications
- Founded in 1990
- Worldwide offices

ARM (ARMHY) is the industry's leading provider of 16/32-bit embedded RISC microprocessor solutions. The company licenses its high-performance, low-cost, power-efficient RISC processors, peripherals, and SoC designs to leading international electronics companies. ARM also provides comprehensive support required in developing a complete system. ARM's microprocessor cores are rapidly becoming the volume RISC standard in such markets as portable communications, hand-held computing, multimedia digital consumer and embedded solutions.[107]

Performance Measures	
Sales (ttm)	$159.5M
Sales Growth (FYE 2000)	68.65%
Profit Margin (ttm)	27.2%
Net Income (ttm)	$43.4
Return-on-Assets (ttm)	24.93%
Total Liabilities	$38.9M
Debt-to-Equity (mrq)	0
Return-on-Equity (ttm)	32.92%
Price-to-Earnings	109.17
Market Capitalization	$4.60B
# of Employees	443

Source: Yahoo! Finance (ARMHY)

CADENCE DESIGN SYSTEMS, INC.

With a worldwide presence and over a decade of experience, Cadence provides leadership in the industry. Its products and services help ensure rapid development for the consumer electronics market.

Cadence Corporate Headquarters,
Buildings 5-9
2655 Seely Road
San Jose, CA 95134
Tel: (408) 943-1234
Fax: (408) 943-0513
www.cadence.com

CEO: Ray Bingham

- Leading supplier of EDA software technology and services
- Founded in 1988
- Locations throughout the world

Cadence (CDN) is the largest supplier of electronic design automation products, methodology services, and design services used to accelerate and manage the design of semiconductors, computer systems, networking and telecommunications equipment, consumer electronics, and a variety of other electronics-based products. Cadence's electronic design automation (EDA) software and services give customers a distinct competitive edge by improving time-to-market, quality, and productivity. Cadence's technology is sold and supported throughout the world. Acquisitions since 1997 have especially focused on companies with SoC capabilities, making the company a major player within that industry.[108]

Performance Measures	
Sales (ttm)	$1.37B
Sales Growth (FYE 2000)	17.04%
Profit Margin (ttm)	4.8%
Net Income (ttm)	$65.6M
Return-on-Assets (ttm)	4.56%
Total Liabilities	$567.9M
Debt-to-Equity (mrq)	.01
Return-on-Equity (ttm)	7.00%
Price-to-Earnings	84.94
Market Capitalization	$5.26B
# of Employees	5,650

Source: Yahoo! Finance (CDN)

MIPS TECHNOLOGIES, INC.

The presence of MIPS, named as an industry leader by several sources, would lend credibility and expertise in the development of Utah's SoC capabilities and offerings.

1225 Charleston Road
Mountain View, CA
94043-1353
Tel: (650) 567 5000
Fax: (650) 567 5150
www.mips.com

CEO: John Bourgoin

- Recently passed the cumulative 100 millionth mark for processors shipped
- Founded in 1984; made an initial public offering June 30, 1998
- Undisputed number one RISC architecture in the world

MIPS Technologies (MIPS) is a leading provider of industry-standard processor architectures and cores for digital consumer and network applications. The company designs and licenses high-performance, high-value, embedded 32- and 64-bit intellectual property and core technology for digital consumer and embedded systems market. MIPS Technologies' reduced instruction-set computing (RISC) designs are licensed to leading semiconductor suppliers, foundries, ASIC developers, and system OEMs for use in products such as set top boxes, digital cameras, video game systems, routers and handheld computing devices. MIPS Technologies and its licensees offer the widest range of robust, scalable processors in standard, custom, semi-custom and application-specific products. By integrating MIPS processor cores into their products, SoC designers can rapidly build integrated SoC solutions for a variety of markets.[109]

Performance Measures	
Sales (ttm)	$92.6M
Sales Growth (FYE 2000)	25.28%
Profit Margin (ttm)	26.5%
Net Income (ttm)	$24.5M
Return-on-Assets (ttm)	20.44%
Total Liabilities	$17.0M
Debt-to-Equity (mrq)	0
Return-on-Equity (ttm)	24.75%
Price-to-Earnings	29.34
Market Capitalization	$692.3M
# of Employees	174

Source: Yahoo! Finance (MIPS)

COMPUTERS:

LSI LOGIC

Named as a leader in the industry by multiple sources, LSI is looked to by others to set precedence in the semiconductor market.

1551 McCarthy Blvd
Milpitas, CA 95035
Tel: (866) 574-5741

www.lsilogic.com

CEO: Wilfred J. Corrigan

- Pioneered the ASIC (Application Specific Integrated Circuit) industry
- Targets four high-growth, high-volume markets - Broadband Communications, Networking Infrastructure, Storage Components and SAN (Storage Area Network) Systems
- Founded in 1981

LSI Logic (LSI) is a leading designer and manufacturer of communications and storage semiconductors for applications that access, interconnect and store data, voice and video. In addition, the company supplies storage network solutions for the enterprise. The company specializes in ASICs and SoCs.[110]

Performance Measures	
Sales (ttm)	$2.64B
Sales Growth (FYE 2000)	31.02%
Profit Margin (ttm)	4.5%
Net Income (ttm)	$119.1M
Return-on-Assets (ttm)	3.06%
Total Liabilities	$1.9M
Debt-to-Equity (mrq)	.38
Return-on-Equity (ttm)	5.17%
Price-to-Earnings	52.16
Market Capitalization	$5.92B
# of Employees	7,221

Source: Yahoo! Finance (LSI)

STMICROELECTRONICS

Because of its experience, size, and domination in the semiconductor industry, STMicroelectronics makes an excellent candidate as an anchor company for the development of an SoC hub.

U.S. Headquarters
1310 Electronics Dr.
Carrollton, TX 75006
Tel: (972) 466-6000
Fax: (972) 466-6001
www.st.com

CEO: Pasquale Pistorio

- World's third largest semiconductor company
- Formed June 1987
- 12 R & D centers, 33 design and application centers, 74 sales offices in 27 countries

STMicroelectronics (STM) is a global independent semiconductor company that designs, develops, manufactures, and markets a broad range of semiconductor integrated circuits and discrete devices used in a wide variety of microelectronic applications, including telecommunications systems, computer systems, and consumer products.

Performance Measures	
Sales (ttm)	$8.03B
Sales Growth (FYE 2000)	54.57%
Profit Margin (ttm)	19.4%
Net Income (ttm)	$1.55B
Return-on-Assets (ttm)	15.51%
Total Liabilities	$5.7B
Debt-to-Equity (mrq)	.45
Return-on-Equity (ttm)	27.52%
Price-to-Earnings	20.91
Market Capitalization	$30.9B
# of Employees	34,500

Source: Yahoo! Finance (STM)

STMicroelectronics has emerged as one of the world leaders in SoC technology, supplying SoC solutions for a wide range of applications such as Set-Top Boxes and Hard Disk Drives. Its success has been the result of a consistent strategy designed to offer customers a comprehensive SoC capability, including processes, design methodologies, unrivalled system know-how and highly efficient volume manufacturing.[111]

DESIGN & IP:

AVANT! CORPORATION

Avant!'s leadership and worldwide presence in the electronic design automation (EDA) and intellectual property (IP) segments of the SoC industry make it an attractive candidate as an SoC anchor company in Utah.

46871 Bayside Parkway
Fremont, CA 94538
Tel: (510) 413-8000
Fax: (510) 413-8080
www.avanticorp.com

CEO: Gerald. C. Hsu

- 26 percent of its revenue invested in R&D, the highest rate in the industry by a significant margin
- Over 65 offices in 18 countries
- Formed in 1985

Avant! (pronounced ah-VAHN-tee) Corporation (AVNT) develops, markets, and supports integrated circuit (IC) design automation software solutions (from system definition to mask synthesis) for the rapid design of multimillion gate products including SoC. These ICs power the consumer electronics, Internet infrastructure, wireless, telecommunications, and automotive products. The company is the leading provider of physical foundation IP libraries for IC design and provides a full suite of software for integrated circuit design, process simulation, device modeling, and mask synthesis.[112]

Performance Measures	
Sales (ttm)	$366.5M
Sales Growth (FYE 2000)	17.94%
Profit Margin (ttm)	13.3%
Net Income (ttm)	$48.6M
Return-on-Assets (ttm)	9.26%
Total Liabilities	$216.0M
Debt-to-Equity (mrq)	0
Return-on-Equity (ttm)	13.92%
Price-to-Earnings	13.76
Market Capitalization	$629.5M
# of Employees	1,330

Source: Yahoo! Finance (AVNT)

CPU TECHNOLOGY, INC.

As a leading designer and manufacturer of compatible embedded computers with proprietary intellectual capital and a high-profile customer base, CPU Tech is poised for continued growth and leadership in the system-on-a-chip market.

4900 Hopyard Road, Suite 300
Pleasanton, CA 94588
Tel: (925) 224-9920
www.cputech.com

CEO: Edward King

Designs solutions for a number of Fortune 100 companies and the U.S. Government

Over the last 10 years, CPU Tech's average EBITDA has exceeded the industry average

Founded in 1989, pre-IPO

CPU Tech is a leading provider of system-on-a-chip based processor modules and services for the high-end embedded systems market. The company's proprietary design process for developing modules is based on its automated validation process, ensuring compatibility, scalability, and high reliability at affordable costs.

CPU Tech's advanced technology enables it to modernize hardware and add new capabilities, while protecting customers' investment in proven software and tools. To maintain a leading edge in its market, the company invests heavily in research and development for processor and automation technology, owning and controlling all associated intellectual property.

Quick Facts	
Sales (2000)	$2.5-5M
Funds Raised	N/A
Major Investors	N/A
Credit Rating	Satisfactory
# of Employees	30

Source: LEXIS-NEXIS, U.S Business Directory

CPU Tech has four complimentary business units: Reliable Systems, aimed at designing long term scalability into high reliability systems; High Assurance Processors, aimed at developing a new generation of parallel processing architecture; Automated Validation Technologies, aimed at delivering high reliability products cost effectively; and Validated Modernization, aimed at enabling true scalability for high reliability embedded systems. The company serves a number of vertical industries including communications, avionics, complex control systems, and medical electronics.

CPU Tech has been profitable since its incorporation in 1989. Additionally, the company has experienced booming growth over the last two years, resulting in its business backlog increasing more than thirty times.

MENTOR GRAPHICS CORPORATION

A world leader in the design function of the SoC industry, Mentor Graphics would function well as an anchor company in the development of Utah's SoC hub.

8005 S.W. Boeckman Rd.
Wilsonville, OR 97070
Tel: (503) 685-7000
Fax: (503) 685-1204
www.mentorgraphics.com

CEO: Walden C. Rhines

- Technology leader in electronic design automation (EDA)
- 55 distribution locations worldwide
- Founded 1981

Mentor Graphics (MENT) is a world leader in electronic hardware and software design solutions, providing products and consulting services for the world's most successful electronics and semiconductor companies. The company's EDA solutions enable companies to send better electronic products to market faster and more cost-effectively. The company offers innovative products and solutions that help engineers overcome the design challenges they face in the increasingly complex worlds of board and chip design -where deep submicron (DSM) technology and SoC design multiply the challenge of getting great product ideas to market.[113]

Performance Measures	
Sales (ttm)	$616.2M
Sales Growth (FYE 2000)	15.40%
Profit Margin (ttm)	9.9%
Net Income (ttm)	$61.0M
Return-on-Assets (ttm)	12.93%
Total Liabilities	$211.7M
Debt-to-Equity (mrq)	.02
Return-on-Equity (ttm)	20.95%
Price-to-Earnings	29.42
Market Capitalization	$1.68B
# of Employees	2,750

Source: Yahoo! Finance (MENT)

PALMCHIP CORPORATION

Specifically focused on SoCs, Palmchip dedicates all of its resources to the development of that industry. The company is currently shopping for a new location and has expressed interest is the Salt Lake region.

2595 Junction Ave. 2nd Floor
San Jose, CA 95134
Tel: (408) 952-2000
Fax: (408) 570-0910
www.palmchip.com

CEO: Jauher Zaidi

- Leader in the development and license of re-usable, configurable processor platform semiconductor IP building blocks for SoC Solutions
- Founded in 1996, pre-IPO, venture funded company
- Headquartered in San Jose, California, with an R&D facility in Loveland, Colorado, and sales offices worldwide

Palmchip Corporation develops and licenses SoC development platforms for embedded IC solutions. Key target applications include networking, portable communications and computing, storage, and multimedia. The company offers general-purpose platforms that contain interfaces to today's popular embedded processors. It also offers application-targeted platforms. Palmchip's IP is based on its CoreFrame(R) integration architecture. This technology is independent of processor, I/O or foundry, allowing designers flexibility in porting IP from any number of sources. Palmchip DirectConnect(TM) partners offer a range of third-party IP, software, and design tools that are compatible with the CoreFrame(R) architecture.[114]

Quick Facts	
Sales (2000)	$5-10M
Funds Raised	$13M
Major Investors	Beeson Gregory, ARM
Credit Rating	Good
# of Employees	38

Source: LEXIS-NEXIS, U.S Business Directory

TENSILICA

Tensilica's tools have the ability to shave months off of the typical development time for custom-designed products, making the company a strong contender in its niche in the industry. Tensilica was also named as one of Red Herring's 100 for 2001.

3255-6 Scott Blvd.
Santa Clara, CA 95054
Tel: 408-986-8000
Fax: 408-986-8919
www.tensilica.com

CEO: Chris Rowen

- Total capitalization of the company is $64 million
- Eight locations throughout the world
- Incorporated in 1997; strong candidate for IPO this year

Tensilica was founded to address the fast-growing market for configurable processors and software development tools for high volume, embedded systems. Using the company's proprietary Xtensa Processor Generator, SoC designers can develop a processor subsystem hardware design and a complete software development tool environment tailored to their specific requirements in hours. Tensilica's solutions provide a proven, easy-to-use, methodology that enables designers to achieve optimum application performance in minimum design time. Partners include Xilinx and Cadence Design Systems.[115]

Quick Facts	
Sales (2000)	$33M
Funds Raised	$33M
Major Investors	Oak Investment Partners, Foundation Capital, Conexant Systems, Cisco Systems
Credit Rating	Good
# of Employees	130
Source: LEXIS-NEXIS, U.S Business Directory	

ACADEMIC RESEARCH

As was stated by a CTO of a Utah-based SoC company, research institutions are vital to the SoC industry. Eighty-three percent of survey respondents stated that locally available research institutions and universities are at least somewhat important, with 39 percent advocating very important (Appendix 1). Research and development in the SoC industry is partially driven by governmental research institutions as well as both private and public universities. But for the SoC industry, even more important than the research surfacing from academic institutions are the graduates. Seventy-eight percent of survey respondents labeled a locally available, highly skilled workforce as very important, the strongest indicator among all asked within the survey (Appendix 1). All companies interviewed have relationships with local universities serving both a research function and as a potential employee-base. Silicon Valley SoC design companies cluster near Stanford University in order to hire graduates and facilitate research projects.

Eighty-three percent of survey respondents stated that locally available research institutions and universities are at least somewhat important. But for the SoC industry, even more important than the research surfacing from academic institutions are the graduates.

Utah is uniquely situated to facilitate these same relationships between SoC companies in Utah and its universities. Brigham Young University (BYU), the University of Utah (U of U), and Utah State University (USU) are located within about two hours of each other and are centrally located around Salt Lake City. All three schools have research either directly or indirectly related to SoC that could help support an innovative SoC market within the State of Utah. However, a VP of a Utah company within the industry warns that university graduates need to be better prepared for work in an industry setting. Programs such as the Capstone Program at BYU in which engineering seniors complete a project with a local company for academic credit are helping to better prepare students for immediate job placement upon graduation.

Upon conducting interviews with various academic researchers at the three universities mentioned above, we found an overwhelming concern for the goals set by Governor Leavitt with regard to the number of engineering graduates desired in the next five to eight years. They pointed out that in order to have a doubling in the number of engineering graduates in five years, there must be a doubling in the number of enrollees now. In addition to the fact that Utah universities are not currently experiencing the needed enrollment to meet the state's goals, many of the professors that were interviewed felt that they were already overloaded with the current student enrollments. They expressed concern for additional funding, stating that a doubling of students would require a doubling in available resources such as professors, buildings, labs and lab equipment.

When asked why Utah universities were not experiencing the needed increases in enrollment into engineering programs, many professors commented that encouragement to potential students was being given too late. They stated that we must first "reform the Utah elementary technical education system before [we] can talk about advanced technical education."[116] There was a consensus among Utah university professors that if students are to be encouraged into university level engineering programs, the encouragement must start in elementary school and continue through middle and high schools.

The following is a list of current research studies at BYU, U of U and USU that are SoC related. This list is not exhaustive, but rather a snapshot of related research:

- SoC Design Methodologies
  - This research explores the cooperative-design aspects (integrated product development) of SoC chips. In the past, because these systems were not integrated, it was possible to design each component separately from all others in a system. Independent teams would work on the CPU, memory, I/O, etc. and simply assemble each component to create the final product. Because the thrust of SoC chips is to integrate all components onto a single chip, design must now be performed in an integrated manner. The goal of this research is to develop methods by which the SoC design process can be taught to new hires and managed internally.
- Micro-electromechanical Machines (MEMs)
  - This research focuses on the design of micro-mechanical systems on an integrated circuit board. Much of the current research being done in this area centers on actuating these microscopic machines. Many of the machines currently being built on the microscopic level are design using compliant mechanisms.
  - The successful implementation of a MEM system into a SoC design would mean that the mechanical world could interface with the electronic world on a microscopic level. Applications of such an achievement would include: all in one sensors such as an accelerometer that controls a seatbelt or an air bag in a car, gate arrays that require power to be switched but not maintained in a given position, and nonvolatile memory that would be unaffected by electromagnetic radiation.

- Product Modularity
  - When a product is completely modular every function part of that product is removable, while functional parts are removable in a completely integrated product. An example of this distinction is found in the desktop PC and a palm top computer. A desktop PC is completely modular. If you want a new memory or video card, you simply unplug the old and plug in the new. A palm top computer is entirely integrated. If you want a new display you must buy and entirely new system. This research focuses on managing the tradeoffs between total integration and a completely modular design. Chris Mattson, a BYU graduate student, shows how to use a mathematical model to manage such tradeoffs in his thesis. Because SoC designers are continually faced with this dilemma, such research is beneficial in their work.
- Wireless Technologies
  - Much research on short-range wireless devices is being done at Utah's academic institutions. Personal applications such as wireless data communications within the home and on the road that are centered on IR/Bluetooth technology are being studied. In addition, commercially implantable medical devices such as cardiac pacemakers, hormone or medication pumps, and electrical stimulation devices that require communication with the outside world are also being studied and designed. Specific research is being done on antennas to facilitate high-speed wireless data networks for the implantable devices. As wireless technology grows, SoC designers will be able to integrate wireless functions into their chip design.
- Embedded Computing
  - Embedded computing assembles SoCs onto boards for specific applications. The ultimate goal of embedded computing research is ubiquitous computing – increased computing power to solve problems for people without them even knowing that computers are improving their lives. Smart clothes that adjust ventilation depending on the weather are an example of ubiquitous computing. Other embedded computing applications are smart appliances and smart cars.
- Micro Batteries
  - To date, a power supply has not yet been integrated onto an SoC itself. Batteries as thin as a human hair have been made, using the same low-cost/high volume fabrication processes used to make MEMS and other integrated circuits. Both rechargeable and nonrechargeable batteries are under development. Batteries can be formed into a variety of shapes or sizes, with voltages, capacities,

and power capabilities to match a wide range of needs. A group at BYU is working as part of a multidisciplinary micro system design and integration group (MMIDI) to integrate micro batteries with electronics and MEMS to form a micro power system.

- Circuit Design
  - o Research in the area of computer architecture and VLSI systems in general, as well as self-timed and asynchronous systems research is being performed at the university level. One aspect of this research involves compiling concurrent communicating programs into asynchronous VLSI circuits. The current system allows programs written in a subset of occam, a concurrent message-passing programming language based on CSP, to be automatically compiled into a set of self-timed circuit modules suitable for manufacture as an integrated circuit. Research investigating the effects of asynchrony on computer systems architecture at a higher level is also being done. To explore these ideas researchers are building a series of prototype asynchronous computer systems out of FPGA and custom VLSI chips.
- Low Power IC design
  - o This research focuses on making chips more power efficient. In conjunction, researchers are studying asynchronous circuit designs and formal verification of design. This research focuses on both analog and digital circuit design.
- Real Time Embedded Concurrent Systems
  - o Scientific applications of this research have included the processing of ionospheric radar data, fluid dynamics, spectroscopy data, and the design of distributed database networks, image compression, and task allocation on multiprocessor networks. Approaches to these problems have included sequential and parallel simulated annealing, parallel expectation maximization, parallel genetic algorithms, and the flux-corrected transport algorithm for fluid dynamics. Hybrids of annealing, branch & bound, and genetic algorithms have also been studied. Most of the projects in the past were developed using various parallel dialects of C, occam, and FORTRAN. Over the past year they have started using Java with CSP extensions. This research is valuable to SoC designers of products with any of the above-mentioned applications.
- Digital Signal Processing and Compression
  - o Research includes lossless and near-lossless algorithms for use in the compression of medical imagery. A VLSI chip that is able to compress at rates from 2:1 - 15:1 at 10 Mpixels/s has been completed. This chip can be used for high-quality data compression

in real-time systems. SoC designers dealing with data compression will benefit from this research.

- ASIC Chips
    - Research is being done in image compression ASIC for use in a commercial videophone system and a commercial videoconference system for military systems for very large static images. This research uses a High Level Descriptor Language (HDL) synthesis approach to design.

Below is a list of academic researchers in the State of Utah that are involved in the above listed research fields:

	BYU	U of U	USU
General University Info	378-4636 www.byu.edu	581-7200 www.utah.edu	435-797-1000 www.usu.edu
Engineering Department	378-6300 www.et.byu.edu	581-6911 www.coe.utha.edu	435-797-2775 www.engineering.usu.edu
Mechanical Engineering	378-2625 DEPT • Spencer Magleby 378-3151 "Product Modularity / Product Architecture" magleby@byu.edu • Larry Howell 378-8037 "MEMs" lhowell@et.byu.edu	581-6441 DEPT • Mark Minor Office 587-7771 Lab 587-9018 "MEMs" minor@eng.utah.edu • Sandy Meek Office 581-8562 Lab 581-3140 "MEMs" meek@eng.utah.edu	
Computer Science	378-3027 DEPT • Knutson 378-5319 "Wireless Technologies" knutson@cs.byu.edu	581-8224 DEPT • Al Davis 581-3991 "Circuit Design" ald@cs.utah.edu • Erik Brunvand 581-4345 "Asynchronous VLSI Circuits" elb@cs.utah.edu	797-2451 DEPT • Scott Cannon 797-2015 "Real Time Systems" scott@cannon.cs.usu.edu
Electrical Engineering Computer Engineering	378-4012 DEPT • Mike Wirthlin 378-7601 "SOC Design Methodologies" wirthlin@ee.byu.edu	581-6941 DEPT • Chris Meyers 581-6490 "Integrated Circuit Design & Formal Verification" meyers@ee.utah.edu • Reid Harrison 587-7926 "Low Power Circuits" harrison@ee.utah.edu 581-8224 Computer Engineering Program Phone Number	797-2840 DEPT • Matthew Berkemeier 797-2873 "Real Time Embedded Concurrent Systems" matthewb@ece.usu.edu • Dyke Stiles 797-2806 "Real Time Embedded Concurrent Systems" dyke.stiles@ece.usu.edu • Tamal Bose 797-7227 "Signal Processing" tbose@ece.usu.edu • Scott Budge 797-3433 "Signal Processing" scott@goga.ece.usu.edu • Jake Gunther 797-7229 "Signal Processing" jake@ece.usu.edu • Randy Haupt 797-2840 "Wireless" randy.haupt@ece.usu.edu • Randy Jost 797-0789 "Wireless" rjost@ece.usu.edu • Alan Shaw 797-2986 "ASIC Chips" ashaw@moses.ece.usu.edu
Electronics Engineering	378-6305 DEPT • Richard Helps 378-6309 "Embedded Computers" helpsr@byu.edu		
Physics			797-2857 DEPT • TC Shen 797-7852 "MEMs" tcshen@cc.usu.edu
Chemical Engineering	378-2586 DEPT • John Harb 378-4393 "Micro Batteries" jharb@et.byu.edu		

SURVEY RESULTS

A survey was sent via email to over 100 companies within the SoC industry. Among the 23 respondent companies, 65 percent were private, 35 percent public. Over 60 percent of respondents were an owner / partner / principal or a member of the executive team. Almost three-fourths of the companies had less than 500 employees. 2000 revenues ranged from less than $1 million to over $5 billion, but over 60 percent recorded less than $25 million. Annual revenue growth varied widely, from –28 percent to over 1000 percent, but all but one company realized positive growth, with over 40 percent in the 100 percent or greater range. Of the 22 companies that answered, 64 percent are currently pursuing venture capital or have pursued it in the past, and half are currently planning to expand or relocate within the next year (See Appendix 1 for complete results).

The respondents were asked to rank on a scale of one to five, one being not important and five being very important, the value of 11 different criteria in potential expansion or relocation decisions. The criteria were:

- Locally available customers and suppliers,
- Locally available research institutions and universities,
- Locally available, highly skilled technical labor force,
- Cost of living considerations,
- State business policies,
- Quality of life,
- Geographic location,
- Locally available professional service resources,
- Locally available capital resources,
- Quality of local transportation infrastructure, and
- Close proximity to a major urban center.

A locally available, highly skilled technical labor force resulted in the greatest consensus among respondents, with 78 percent labeling it "very important."

A locally available, highly skilled technical labor force resulted in the greatest consensus among respondents, with 78 percent labeling it "very important." Research institutions and universities also emerged as important, with 57 percent of respondents giving a ranking of at least 4. Quality of life is also important, with 91 percent of respondents giving a ranking of at least 3, although only 22 percent ranked it as 5. Eighty-three percent of respondents ranked cost of living as at least 3. Locating near a major urban center is an important, but not the most important, factor, with 48 percent of responses at 4 and another 17 percent at 5. Local professional services seem to follow, with 48 percent of responses at 4, and another 9 percent at 5. Seventy-eight percent of respondents ranked geographic location as either a 3 or a 4. Forty-three percent of responses for state business policies were a 3, making the criteria somewhat important. Local customers and suppliers appear to be of mixed importance depending on the company. Responses to locally available capital resources were fairly evenly mixed among 1 through 4, but only 4 percent ranked it as 5. The quality of transportation infrastructure was also of mixed importance, although it seems to lean towards the less important end of the spectrum.

Utah currently has many of the elements most important to companies in the SoC industry, including a skilled workforce, local universities, a high quality of life, and a reasonable cost of living.

Utah currently has many of the elements most important to companies in the SoC industry, including a skilled workforce, local universities, a high quality of life, and a reasonable cost of living. Although the state lacks local sources of capital resources and local customers and suppliers, these factors may not prevent the development of an SoC hub in the short-run. Cost of living and local universities were the most common responses among respondents as Utah's strengths, while a lack of high tech and semiconductor companies was a repeated weakness. Among Utah respondents, a common weakness was the inability to attract skilled employees to the state, due in large part to the negative perception of the state and the lack of other companies in related industries. When asked to rate Utah's overall technology business environment, 65 percent of respondents gave an "average" ranking, 20 percent gave a "weak" ranking, and 15 percent gave a "strong" ranking. No respondents chose "very weak" or "very strong." The perception of Utah's environment will need to be improved before many companies will show an interest in locating within the state.

CONCLUSION & RECOMMENDATIONS

The question of continued state economic expansion largely hinges on the success of advanced technology economies in the state; by all accounts increasing the state's semiconductor industry should boost the Utah's position an emerging *national* technology hub. Growing the SoC industry will advance this end. Utah hosts a few large firms and many startups, but homegrown companies frequently exit before reaching IPO and maturity due in part to the state's shortage of second- and third-round venture capital. Assuming this problem will endure—at least in the near term—this report advocates an economic development strategy focusing on large firm expansion and medium-sized private firm relocation.

The debate surrounding how to effectively nurture and grow an industry rides on the distinction between cluster economies versus anchor companies. On the one hand, economies of agglomeration within industries emerge only after a "critical mass" of companies reside in close proximity to one another. On the other hand, the presence of several anchor companies or large industry leaders generates incentives for supplier and customer firms to follow. While interview data tend to support the need for anchor companies *before* the benefits of clustering are realized, Utah could hedge itself by following a two-pronged strategy: 1) inducing anchor company expansion and, 2) drawing mature private firms to relocate.

Utah must also take advantage of opportunities that already exist in the State. The state hosts a growing number of satellite offices of major semiconductor firms including Intel, Lucent, Fairchild, and National. While these offices are typically small sales entities, the opportunity exists for greater government outreach. State officials would do well to engage local company principals with the same enthusiasm that is shown to firms exploring relocation and expansion. Industrial assistance funds earmarked for in-state firms and other R&D could strengthen flagging incentives for large firms with expansion potential. This is especially important given the sense among in-state high tech interview respondents that Utah generally ignores local firms while expending nearly all of its economic development resources on outsiders.

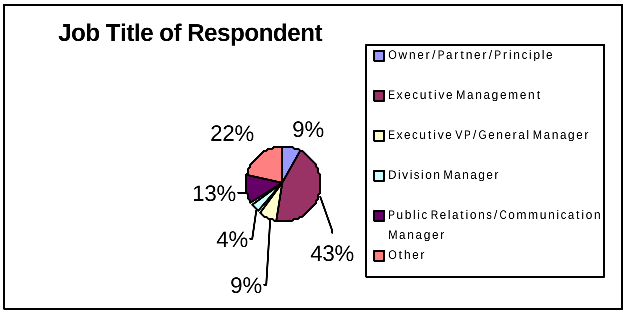
Utah must focus on implementing, not just identifying, policy goals. In order to have trained people ready for employment by future Utah companies, the number of new college enrollees must be increased in the short term. Governor Leavitt has stated that he would like to see the number of engineering college graduates double in the next five years and triple in the next eight. If there is to be a doubling of graduates in five years in a four-year program, the number of students enrolling in these programs must be doubled now. However, if students are going to be guided into engineering programs, they must be encouraged from a young age. In other words, encouragement needs to start at in grade schools and middle schools. In addition, a doubling in the number of engineering college graduates will require a doubling in resources. If this doubling is truly the goal, Utah must increase funding to the state universities so that they can expand their programs. Academic interview respondents generally affirmed these points and expressed concern about the feasibility of current policy goals. Such goals appear to lack the resources and plans necessary for speedy implementation.

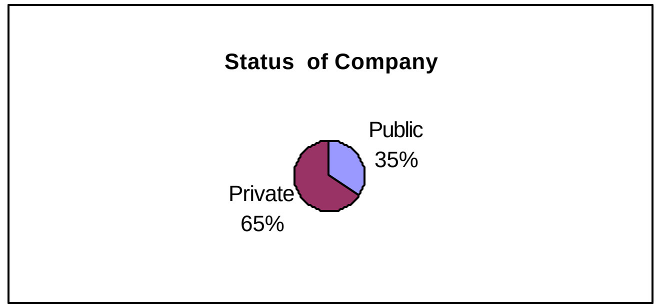
Survey data suggests that the perception of Utah's high tech business environment will need to be improved before companies will show an interest in locating within the state. If 65% of the high tech world sees Utah as an average place to do business, with an additional 20% that see Utah as weak, the chances of a CEO even considering Utah as a place to expand or relocate are highly unlikely. Utah must find a way to brand itself so that business leaders and firms will associate the state with high tech prosperity, business opportunity, and lifestyle advantages. Distinguishing the state's message from that of other competing states represents a major task. However, the state could leverage Olympic visibility to advance its policy goals: aggressive marketing on television and print media could greatly enhance the state's image as a center for entrepreneurs and high tech innovation.

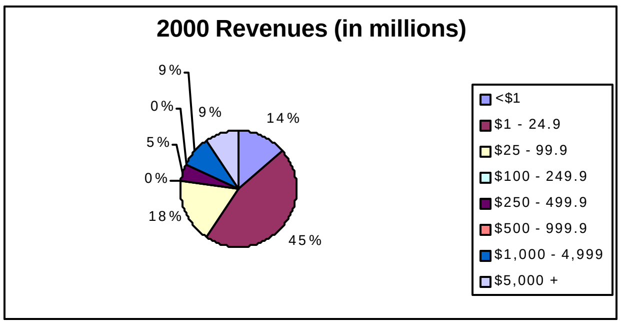
While innovation will drive the SoC market, science and technology alone will not provide sufficient foundation to guarantee state economic growth. Targeting the innovation process requires attention to the capacities complementary to innovation. In particular, manufacturing matters. So does infrastructure. Strategic alliances confer benefits when it comes to developing and capturing value from innovation. While strength in capacities complimentary to R&D will promote economic welfare where imitation is easy, it is not the only solution. A company with outstanding technology and an excellent product can fail to profit from innovation while the imitators succeeded. The state should therefore encourage firms to focus R&D programs on delivering innovations that will have a good chance of benefiting Utah rather than other states (and other firms). The state must do all it can to localize the entire SoC value chain, and encourage its members to form strategic alliances. The key to success for any link in the SoC value chain will be in establishing partnerships in order to provide complete solutions to compelling customer problems.

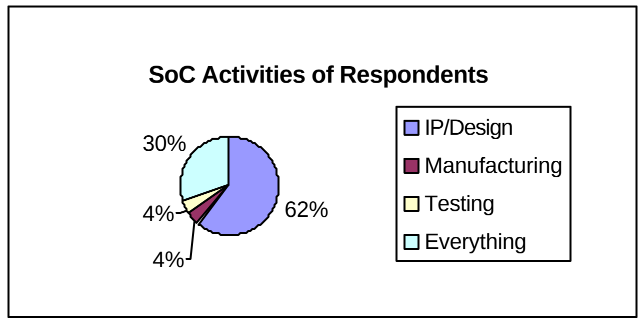
This report has generally suggested the benefit of SoC firms that specialize in design since intellectual property adds tremendous value to SoC products. However, there are powerful implications for states that perceive their comparative advantage to be in innovation. Unless one's trading partners are backward, it will never be enough to have the best science and engineering establishment and the most creative engineers and designers. Since the fruits of scientific effort are increasingly open to all with the capacity to receive, extracting value from a state's science and engineering prowess will require its firms to have competitive capacities in certain of the key complementary assets, such as manufacturing, marketing, and strategic partnering. In many cases this will need to be in-state in order to fashion defensible competitive strategies. Public policies that do not recognize that translating scientific and technological leadership into commercial leadership in most cases requires parallel excellence in capacities complementary to the innovation process may doom a state to economic decline—possibly tempered only by a bounty of Nobel prizes.[117]

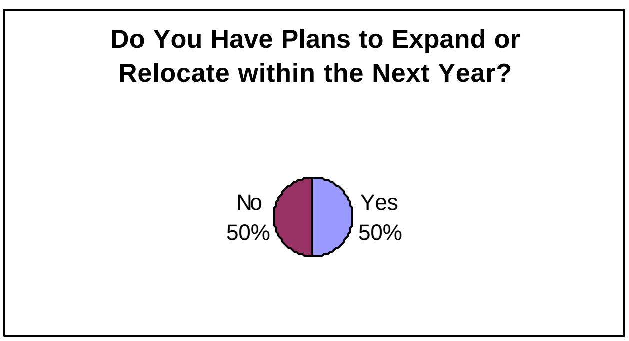
APPENDIX 1: SoC SURVEY RESULTS

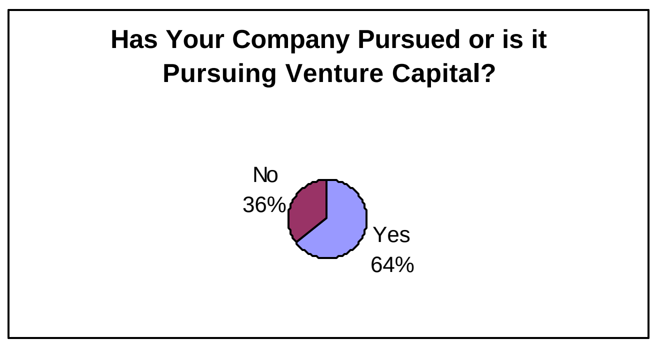


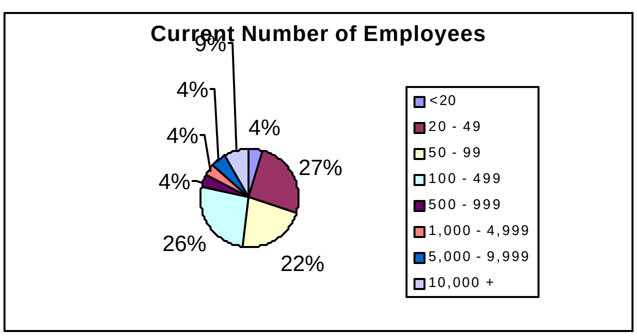


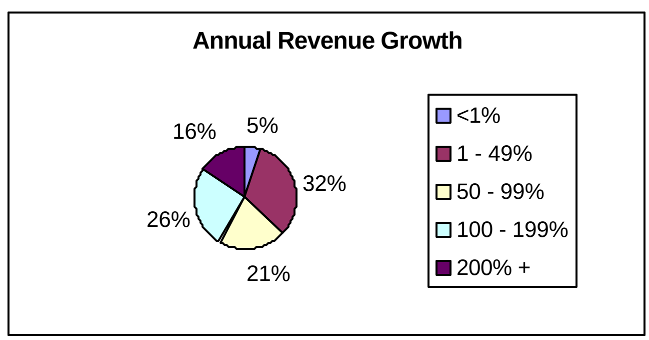


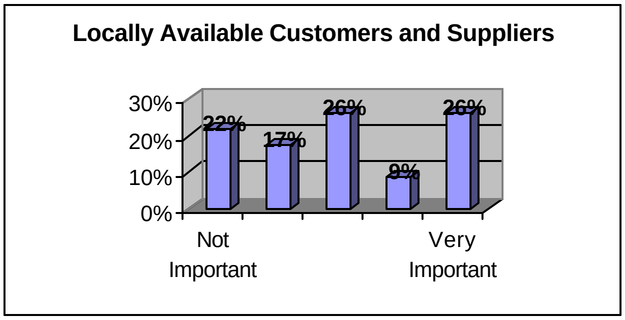











Locally Available Customers and Suppliers
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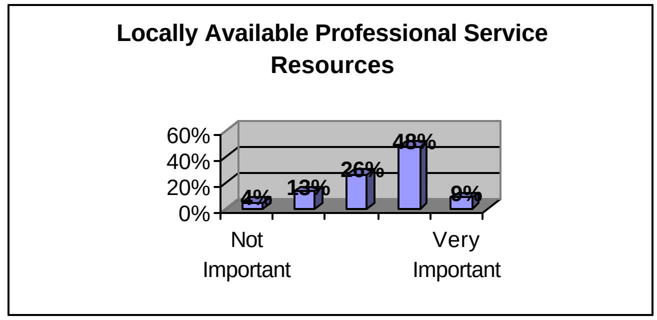
20%
10%
0%
22%
17%
26%
9%
26%
Not Important
Very Important


Locally Available Professional Service Resources
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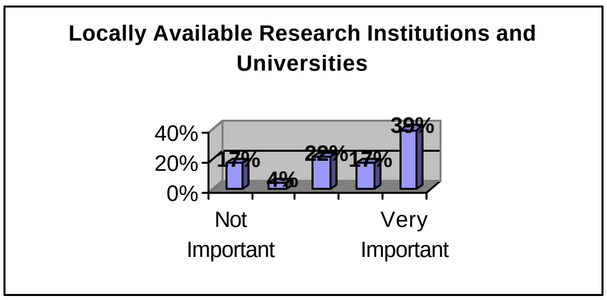
40%
20%
0%
4%
13%
26%
48%
9%
Not Important
Very Important


Locally Available Research Institutions and Universities
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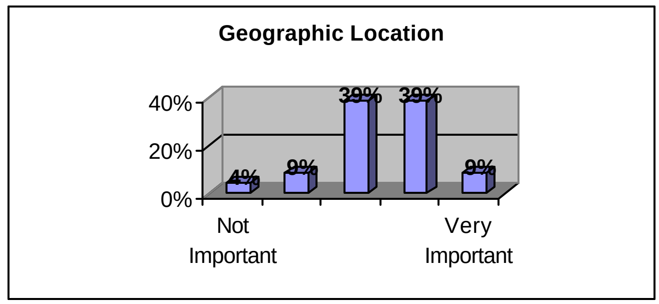
17%
4%
22%
17%
39%
Not Important
Very Important


Geographic Location
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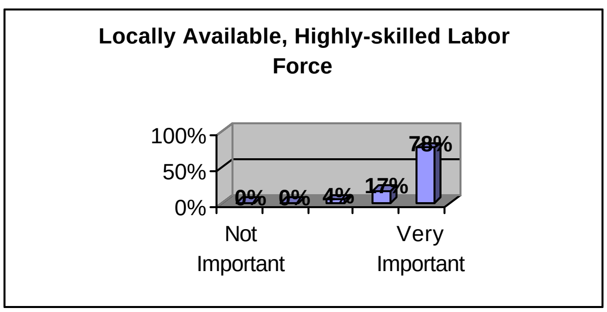
4%
9%
39%
39%
9%
Not Important
Very Important


Locally Available, Highly-skilled Labor Force
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0%
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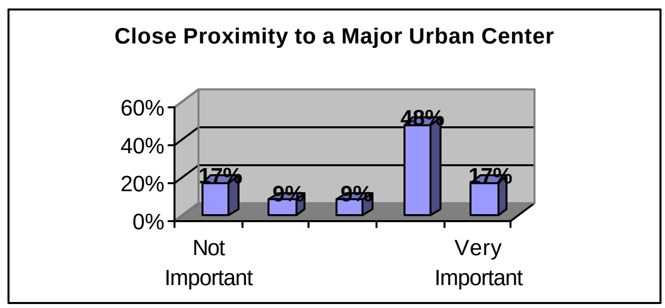
0%
4%
17%
78%
Not Important
Very Important


Close Proximity to a Major Urban Center
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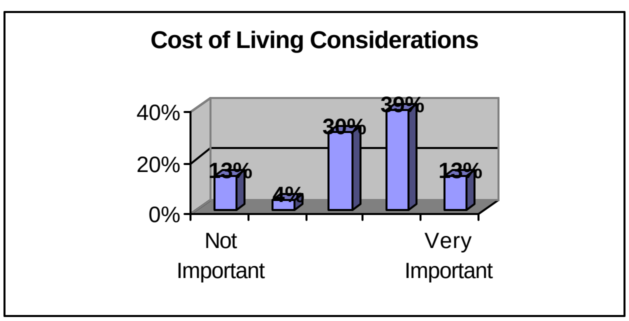
17%
Not Important
Very Important


Cost of Living Considerations
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13%
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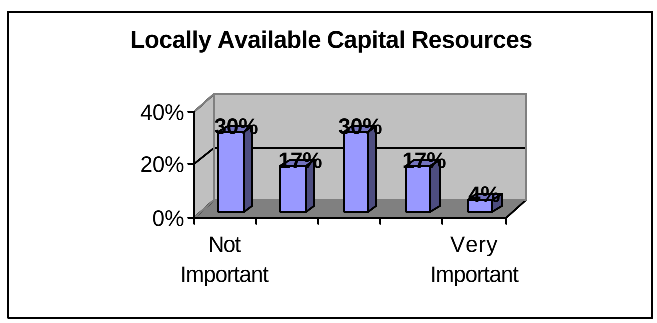
Very Important


Locally Available Capital Resources
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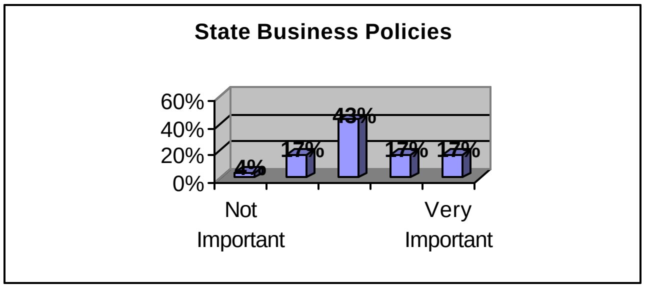
20%
0%
30%
17%
30%
17%
4%
Not Important
Very Important


State Business Policies
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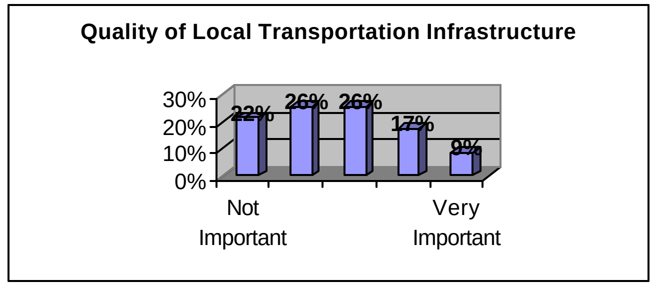
4%
17%
43%
17%
17%
Not Important
Very Important


Quality of Local Transportation Infrastructure
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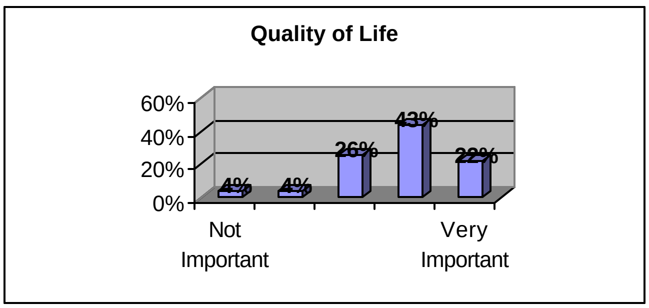
22%
26%
26%
17%
9%
Not Important
Very Important


Quality of Life
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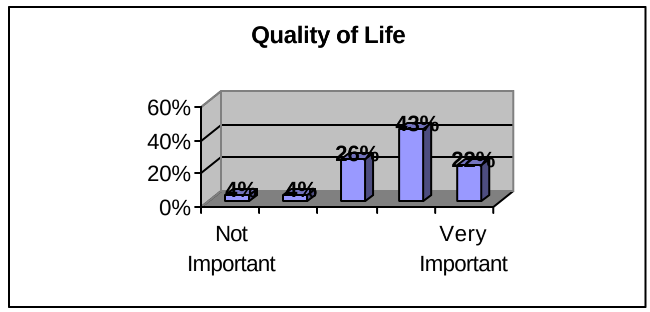
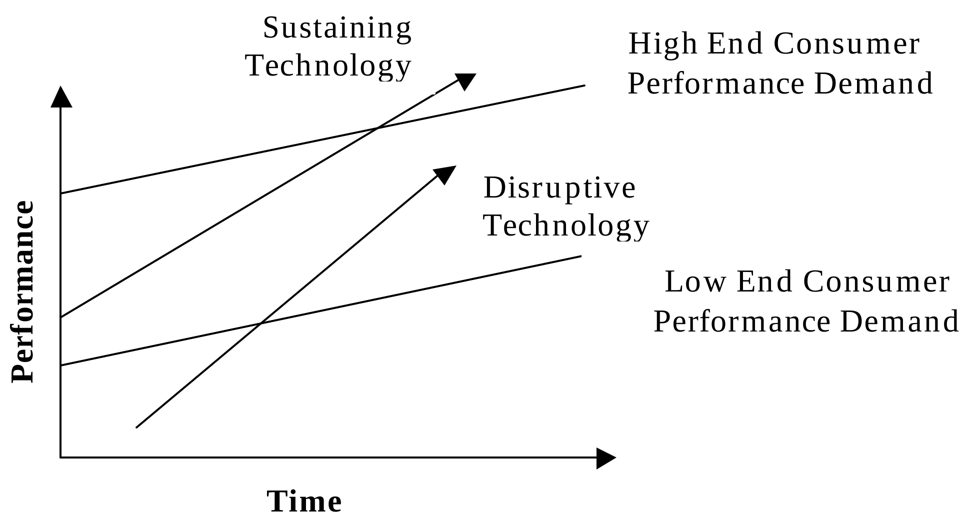
20%
0%
4%
4%
26%
43%
22%
Not Important
Very Important


Quality of Life
60%
40%
20%
0%
4%
4%
26%
43%
22%
Not Important
Very Important

APPENDIX 2: SOC AS A DISRUPTIVE TECHNOLOGY?

Technological innovations can be categorized as either sustaining or disruptive. Sustaining technologies improve product performance of attributes already valued by mainstream customers, while disruptive technologies introduce a very different set of attributes and often perform far worse than current market offerings.[118] Although disruptive technologies appeal only to new, emerging markets at first, performance improves along a steep trajectory and eventually meets the demand of the mainstream market, as shown in the following diagram. The disruptive technology then takes market share from established market leaders in the traditional technology. Identifying a potentially disruptive technology early is critical to the continued success of all companies, especially leading companies that traditionally concentrate only on sustaining technologies, for in it lies the growth potential of the market.



In order for a technology or innovation to be labeled disruptive, it must meet the criteria laid out by Clayton Christensen in his 1997 book *The Innovators Dilemma: When New Technologies Cause Great Firms to Fail*.[119] The criteria are:

- **It enables** a larger population of less skilled or less wealthy people to do something more simply and conveniently that could historically be done only by experts or the wealthy.
- **It exploits** the innovation's unique attributes in new applications rather than stretching to meet the product or service requirements in the mainstream market.
- **It disrupts** markets that are underserved rather than seeking to disrupt overserved markets.
- **It reshapes** the retailing business model to earn profits in a new way.

- **It facilitates** existing patterns of customer behavior rather than assuming a change in customer behavior.
- **It focuses** on a specific customer need and builds a brand position squarely on that need.

Labeling system-on-a-chip technology as disruptive or sustainable is debatable. The rationale for classifying it as **disruptive** is as follows:

SoC chips have many unique design attributes. The all-in-one-architecture of an SoC makes the chip smaller, faster, and more reliable than a comparable conventional system, but an SoC is not hardware upgradeable. Drawing upon these unique attributes, SoC has found application in very specific markets, including military, telecommunications and consumer electronics, and computing. SoCs have been used primarily in applications where the end consumer expects to replace an entire hardware system rather than upgrade components of it, such as a cell phone or PDA. SoC's penetration into these markets does not require a major change in consumer behavior, as the mainstream market has traditionally replaced these devices with a newer version rather than upgraded the existing device. Further, products such as web-enabled cell phones and PDAs, made possible by SoC design, are increasingly allowing mainstream consumers the enjoyment of perks previously enjoyed only by the wealthy.

SoC specifically attacks the problems of reliability and size. In the business-to-business world, firms that adopt an SoC architecture will have fewer problems with product reliability and will be able to produce smaller and faster devices. This is a perfect match for consumers who are continually demanding such devices.

Some within the industry see SoC technology as a **sustaining** rather than disruptive technology. The rationale for this viewpoint is as follows:

The central push in semiconductor related industries has always been for smaller, faster, and more reliable designs. As a CEO of a Utah-based design firm expressed, chip companies have always tried to fit more on less space and SoC is simply a name for that drive, making SoC a sustaining rather than disruptive technology. A BYU business professor who has studied the semiconductor industry believes SoC lacks some of the defining characteristics of a disruptive technology, principally the creation of new markets and diminished initial performance.

Conclusion

This debate may never come to a finite conclusion without consulting with Christensen himself, but classifying SoC as either sustaining or disrupting does not alter the growth potential of this market. Most of the larger semiconductor companies are somehow involved in the development of the technology and SoCs are slated to overtake the majority of the semiconductor industry. Disruptive or not, SoCs represent a tremendous opportunity for all stakeholders within the industry.

APPENDIX 3: BASELINE EXPLANATION

Since most, if not all, semiconductor firms are now aggressively pursuing SoC development and applications, our definition uses "semiconductors" as classified by government standard industrial classification codes (SICs). Similarly, "integrated systems design" captures design companies in the SoC space; for example CPUtech, a leading SoC design firm, falls into the integrated systems. In order to provide an overall industry analysis, listed below are several performance variables that were identified as key performance measures. By providing industry averages for high-tech regions Colorado and Silicon Valley, as well as national averages, this report aims to map the SoC industry firms that have the most direct bearing on Utah's potential SoC market. Standard and Poor's COMPUSTAT database provides data for all public firms including their key financial statistics. Using SICs, COMPUSTAT delivered financial statistics for firms in the SoC space. We have identified the following variables as vital to measuring SoC performance and helpful in comparing specific firms to an industry baseline.

Performance Measures
Market Capitalization - (MM$): The total number of a company's shares multiplied by the current price per share.
Assets - *Total* (MM$): All the property owned by a corporation. Total assets include current assets; fixed assets such as buildings and equipment, and other assets such as licenses and good will.
Income - (MM$): The amount of a company's total sales (revenue) remaining after subtracting all of its costs, in a given period of time (also referred to as "net earnings").
Employment - (M): A chief indicator of company size measured in units of one thousand.
Return on Equity - (%): A percentage that indicates how well common stockholders' invested money is being used. The percentage is the result of dividing net earnings by stockholders' equity. The ROE is used for measuring growth and profitability. By comparing a company's ROE to that of its industry it may be judged against average industry performance.
Price-to-Earnings - (%): An indicator of a stock's value figured by dividing the stock's price by its earnings per share for a 12-month period. Stocks with high P/Es compared to the overall market are typically growth stocks.
Sales - (MM$): A company's total sales minus certain types of returns, allowances and discounts.
Sales Growth - (%): A useful measure of how fast a company's business is expanding. This figure shows the annualized rate of increase (or decrease) in a company's revenue or sales growth.

Total Debt - (MM$): Everything a company owes. Total debt includes long-term debt and current liabilities. Debt can be a good tool for a corporation. It can help the company invest in new plants and equipment that will increase profitability. Too much debt, however, is risky. It locks the company into regular interest payments whether earnings are up or down.
Debt-to-Equity - (%): The ratio of a company's liabilities to its equity (total value of stock). Total debt-equity is the ratio of a company's long-term and current liabilities (debt that will be paid off within one year) to its equity. The higher the level of debt, the more important it is for a company to have positive earnings and steady cash flow.
Profit Margin - (%): Determined by dividing net income by net sales during a time period (usually the past four quarters) and is expressed as a percentage. Net profit margin is a measure of efficiency and the higher the margin, the better. Trends in margin can be attributed to rising/falling production costs or rising/falling price of the goods sold.

Source: http://www.quicken.com/glossary/[120]

SoC Comparative Regional Performance

This report advances several regional baselines to evaluate prospective anchor and growth companies against. As a primary indicator Silicon Valley averages are presented below; secondarily, national level averages and Colorado performance figures are included, as Colorado represents a very similar state to Utah in terms of history and scale. Utah has specialized in software firms, while Colorado now hosts a relatively large share of semiconductor, integrated design, and SoC firms. Colorado is included as a benchmark for Utah SoC companies in the near to medium term. Silicon Valley averages therefore constitute an ideal type of SoC market—orders of magnitude beyond Utah's current SoC space—one that will take many years to achieve in Utah. At present Utah hosts a growing number of strongly positioned private firms such as SliceX, Sorenson Technologies, and Lineo.

SoC Performance, Silicon Valley Firms

Performance Measure	1997	1998	1999	3-Year
Market Capitalization – (MM$)	599.71	809.76	3094.74	1476.70
Assets – Total (MM$)	415.37	402.81	644.53	482.51
Income – (MM$)	8.87	-3.31	47.35	16.38
Employment – (M)	1.27	1.40	1.60	1.43
Return on Equity – (%)	33	17	-180	-43
Price-to-Earnings – (%)	37.84	15.66	50.76	34.07
Sales – (MM$)	278.55	262.52	379.29	304.14
Sales Growth – (%)	0.68	1.04	0.90	0.87
Total Debt – (MM$)	163.14	175.71	250.84	195.32
Debt-to-Equity – (%)	0.18	-1.16	1.38	0.05
Profit Margin – (%)	-0.13	-0.05	0.03	-0.05

SoC Performance, Colorado Firms

Performance Measure	1997	1998	1999	3-Year
Market Capitalization – (MM$)	19.07	35.80	159.16	85.59
Assets – Total (MM$)	17.76	47.49	70.89	47.89
Income – (MM$)	-3.04	-9.20	-18.48	-11.37
Employment – (M)	0.21	0.41	0.58	0.42
Return on Equity – (%)	-308	- 191	-105	-201
Price-to-Earnings – (%)	4.33	1.73	-8.19	-2.58
Sales – (MM$)	23.43	39.67	59.64	43.59
Sales Growth – (%)	0.14	1.57	0.47	0.77
Total Debt – (MM$)	10.00	39.58	53.43	36.55
Debt-to-Equity – (%)	4.31	2.45	1.88	2.75
Profit Margin – (%)	-0.36	-0.10	-0.29	-0.24

SoC Performance, US Firms

Performance Measure	1997	1998	1999	3-Year
Market Capitalization – (MM$)	309.11	516.40	2117.30	980.94
Assets – Total (MM$)	212.62	229.54	343.45	261.87
Income – (MM$)	5.53	-2.50	15.80	6.28
Employment – (M)	0.89	1.21	1.34	1.15
Return on Equity – (%)	-8	-4	-58	-20
Price-to-Earnings – (%)	13.68	3.42	39.60	18.90
Sales – (MM$)	214.71	207.21	245.36	222.43
Sales Growth – (%)	0.64	0.61	0.59	0.61
Total Debt – (MM$)	90.89	101.11	130.92	107.64
Debt-to-Equity – (%)	0.85	-0.22	0.92	0.52
Profit Margin – (%)	-0.13	-0.24	-0.03	-0.13

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